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ABSTRACT

Planners in multicounty rural areas can use the Rural Development, Activity Analysis Planning (RDAAP) model to try to influence the optimal growth of their areas among different general economic goals. The model implies that best industries for rural areas have: high proportion of imported inputs; low transportation costs; high value added/output ratio and value added/labor ratio; low percentage of labor skill that is most scarce; and low capital/output ratio. The model likewise suggests that conversion of agricultural land from the land use pattern of lower income farms to that of higher income farms is always desirable in a region. The linear programming model was specifically applied, in this report, to a region of northwest Arkansas comprising Benton, Madison, and Washington Counties (BMW region). Alternative objectives included the following: regional balance-of-trade surplus, regional balance-of-payments surplus, gross regional product, local value added, and a regional rate-of-return index. Data were obtained for 1960-70 to compare growth of employment by industry in the model with the actual growth in the area. Because a portion of the BMW region has recently been designated a Standard Metropolitan Statistical Area (SMSA), this study can provide a vehicle for examining how an area might be developed optimally from a rural to a more urban status. (AH)

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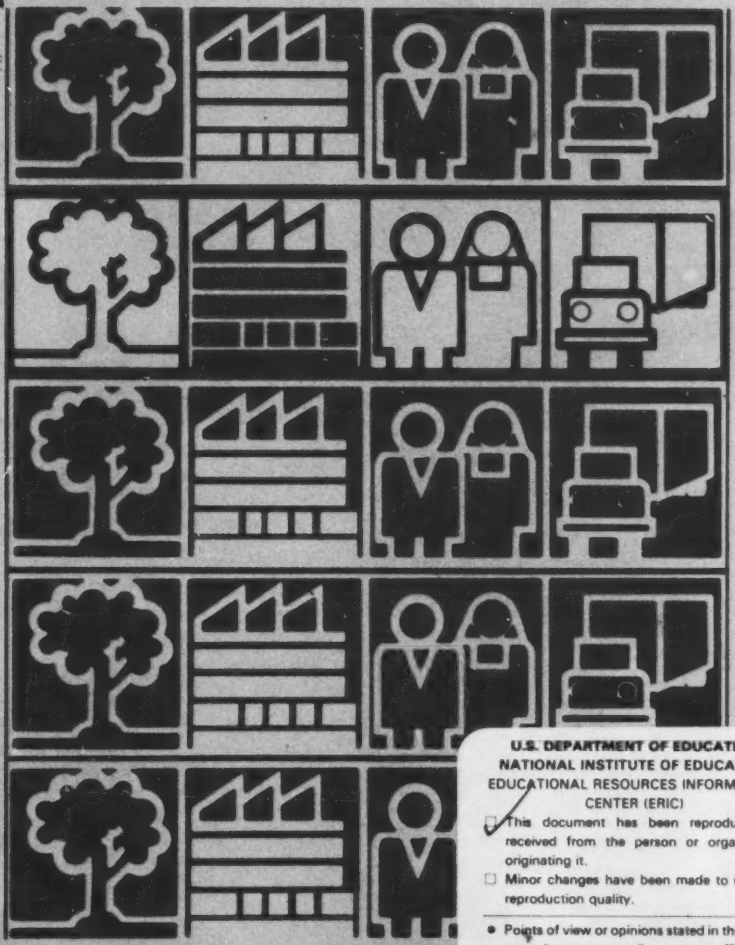
Technical Bulletin No. 1689

Economic Planning for Multicounty Rural Areas

Application of a Linear Programming Model in Northwest Arkansas

Daniel G. Williams



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Economic Planning for Multicounty Rural Areas: Application of a Linear Programing Model in Northwest Arkansas, by Daniel G. Williams. Economic Development Divison, Economics and Statistics Service, U.S. Department of Agriculture. Technical Bulletin No. 1653.

Abstract

A linear programming economic development model can help regional planners influence the most desirable type of growth for rural areas. Optimal resource use, investment, and industry mix for manufacturing, services, government, and agriculture are reviewed for nine regional macroeconomic goals, with the tradeoffs evaluated for attaining one objective over another. Multiple regression analysis allows the most desirable industries to be identified by economic characteristics such as capital/output and value added/labor rather than product type. Although the results are specific for a region in northwest Arkansas, the general conclusions should be valid for other areas as well.

Keywords: Linear programming, multiple regression, rural development, regional goals, economic planning, SIC codes.

Washington, D.C. 20250 June 1981

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Summary

Planners in multicounty rural areas can profitably use the RDAAP (Rural Development, Activity Analysis Planning) economic model, especially its general conclusions, to try to influence the optimal growth of their areas among different general economic goals. The model implies that the best industries for rural areas have the following attributes:

—High proportion of imported inputs.
—Low transportation costs.
—High value added/output ratio and value added/labor ratio.
—Low percentage of the labor skill that is most scarce.
—Low capital/output ratio.

The model likewise suggests that conversion of agricultural land from the land use pattern of lower income farms to that of higher income farms is always desirable in a region, regardless of the region's general economic objective.

The linear programming model was specifically applied, in this report, to a region in northwest Arkansas comprising Benton, Madison, and Washington Counties (the BMW region). The model's alternative objectives were to maximize the following: regional balance-of-trade surplus, regional balance-of-payments surplus, gross regional product, gross regional product (assuming some labor force immigration), local value added, local wage bill, local employment, regional industry-wide profits, and a regional rate-of-return index.

Data were obtained for the years 1960-70 to compare the growth of employment by industry in the model with the actual growth in the area. Such an economic planning model can be used to evaluate the most efficient organization of local resources relative to an aggregate goal for the region, such as maximization of gross regional product or minimization of local unemployment.

Because a portion of the BMW region (Benton and Washington Counties) has recently been designated a Standard Metropolitan Statistical Area, this study can provide a vehicle for examining how an area might be developed optimally from a rural to a more urban status. Various experiments resulting in different versions (modifications) of the model were undertaken in order to improve the model and to simulate alternative regional assumptions.

Tradeoff curves were created between pairs of alternative regional objectives with one objective maximized while the other was varied parametrically. Shadow price results for the constrained exports of manufactures were also examined. Multiple regression analysis on these shadow prices was undertaken (1) to explain these export valuations in terms of nine industry economic characteristics, rather than in terms of product type and (2) to infer export shadow prices to industries not already included in the linear programming model.

The model, especially its general conclusions, seems useful for economic planning. Some of the model's general economic planning principles or strategies, in addition to those cited above, are:

— Some industry economic characteristics affect the level of many or most of the regional objectives; others affect only one or a few of the objectives.

— Having to make tradeoffs among different objectives seems to be a typical pattern; a gain (loss) in one objective implies a loss (gain) in another, for a given quantity of exports and labor, and for a fixed level of technology.

— The regional objectives tend to fall into two groups: those that lean more toward the interests of capital or management (maximizing balance-of-trade surplus, balance-of-payments surplus, gross regional product, industry-wide profits, and industry rate-of-return index); and those preferred by labor (maximizing local value added, local wage bill, and local employment).

—The tradeoff range between a capital-oriented and a labor-oriented objective is much larger than between pairs in each group.

—In the optimal solution, levels of industry employment, types of industry, industry production levels, and regional economic indictors (like balance-of-trade surplus) are, in general, more similar for the capital-oriented objectives and for the labor-oriented objectives, than for any two objectives, one from each group.

—Both the tradeoff range and the tradeoff possibilities between pairs of alternative regional objectives

expand for more open regions (those regions with increased potential for export trade and labor flows).

—Opportunity costs between pairs of alternative regional objectives remain fairly constant for more closed regions, but increase for more open regions.

—A sensible planning practice is to identify which pairs of goals are likely to lead to conflict, and then to have the local political process, for example, select a compromise from among the solutions that are efficient with respect to both goals.

ECONOMIC PLANNING FOR MULTICOUNTY RURAL AREAS

Application of a Linear Programming Model in Northwest Arkansas

Daniel G. Williams
Regional Economist

Introduction

This report analyzes how a multicounty rural area can attain general economic goals and the tradeoffs involved in giving some goals priority over others. The discussion, although specific to Benton, Madison, and Washington Counties in northwest Arkansas (the BMW region), should be useful to planners and their technical staffs in other regions as well. Planners in areas similar to the BMW region will find useful the specific results and the methods used, while planners in other multicounty rural areas will find more useful the general results and methods. Perhaps the most important audience will be economists and other consultants concerned with regional economic development who should find useful the general results and the methodologies used in the study.

The regional economic goals considered are maximizing regional balance-of-trade surplus, regional balance-of-payments surplus, gross regional product, gross regional product (with labor immigration assumed), regional value added, regional aggregate wage bill, regional employment, regional industry profits, and regional industry rate-of-return index. Such goals constitute only a portion of the entire regional planning problem. A rural economic development planning model is used to illustrate what such a model can tell local area planners and thereby aid them in their planning. The model is called RDAAP (Rural Development, Activity Analysis Planning). The output of the model yields the industry mix, regional import and export levels, employment requirements by skill level, and so forth.

Leaders in multicounty rural areas face numerous problems in attempting to improve the well-being of the area's inhabitants. The overall planning authority, to the extent that it exists, resides in agencies or institutions such as councils of government (COG's) or in appointed or elected officials with jurisdiction over such areas as the governors' substate planning districts, local development districts, and so forth. The power of these agencies varies from area to area but most are advisory bodies rather than administrative. Area growth and development planning includes planning for health needs, employment requirements, increases in per capita income, educational goals, transportation and recreation facilities, environmental improvements, and others. The achievement of many of these more specific goals is, of course, interrelated as is the achievement of the more general regional economic goals discussed in this bulletin.

A region faces many growth choices, and it is hoped that some of the model's solutions may provide assistance in making these choices. The discussion is as nontechnical as possible, although some sections may be too technical for some readers. Those sections are noted as they appear so that they can be skimmed or omitted by such readers. Conversely, a reader who wishes a more detailed description of the material presented may want to consult the parent document of this report [*13*] as well as other articles and reports that explore some of the results more deeply [*14, 15, 16, 17, 18, 19, 20, 21, 22*].[1] The individual components and mathematical structure of the linear programming model used are given in [*21*]. The model and study(s) upon which the present model (RDAAP) is based were developed by the Stanford Research Institute (SRI) under contract to the U.S. Department of Agriculture. The original SRI model, the "Kentucky Model," was developed by Spiegelman [*5*]. Further development of the model by SRI is given in [*3* and *6*].

The style of this bulletin is discursive, covering successive experiments with various versions of the model, each devised to help illuminate or resolve a specific question. Each version is explored, and its strengths and weaknesses assessed. Some of the model versions incorporate improvements over other versions. These improvements were added to help make the model more realistic and, therefore, more likely to be applicable to the area. The best *planning* version of the model uses activity types and input coefficients that in general

[1]Italicized numbers in brackets refer to sources cited in the References section at the end of this report.

make the model more realistic as compared with the "real world."[2] The fact that these more realistic assumptions have also led generally to realistic results is reassuring. Insights and other observations on the model results with respect to planning optimal economic growth will be discussed. Some of the results are general, some specific, for the various model versions.

The results and model versions described here do not exhaust the possibilities for useful research on the model structure or on its results. Improvements can still be made in the model, some of which are indicated in the text. The researcher must make choices of which topics to explore and develop more fully and where to use simplifying assumptions. The original intent of this work was to assess the strengths and weaknesses of the model as it was developed by the Stanford Research Institute (SRI). Where possible, improvements are incorporated based on this assessment.

This report includes a minimum of tables and other specific data and results. The specific output of any model depends upon the values assumed for the constraints, coefficients, degree of industry disaggregation, and the number and nature of the simplifying assumptions. Data or sectoral aggregation errors can lead to possible output errors. Less emphasis will be placed on the exact results and more on general results obtained from the research.

As an example of this more general focus, as will be discussed later, it may be better to interpret optimal industries selected by the programming algorithm not merely in terms of their Standard Industrial Classification (SIC) number, but also in terms of industry characteristics such as the capital/labor ratio [*18, 19*].[3] A model with a limited number of specific industry choices from among all

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[2]One version of the model (Basic Model) is a *predictive*, not *planning* version. A *planning* model does not necessarily have to *predict* well, although such a concurrence does tend to validate the planning "prescriptions" derived from the model's results. As indicated later in this report, prediction can be in terms of industry characteristics (such as capital/output ratio) rather than merely in terms of specific industry types [*18, 19*].

A model contains both exogenous and endogenous variables. In a planning model the former have to be predicted before the model can be run. The results for the model's endogenous variables can then be used as predictions of "real world" results. This is attemped using one of the RDAAP model versions. Note, however, that a poor prediction by the endogenous variables does not necessarily imply that the predictions of exogenous variables were inadequate.

[3]The "Standard Industrial Classification" (SIC) of the U.S. Dept. of Commerce (where one-digit industry groups are the most aggregated industry group as to type of product, and four-digit groups are the least.

theoretically possible choices, must not be viewed too strictly with respect to industry product alone.

Although the specific model results obtained should be reasonably accurate, the emphasis is on the qualitative or interpretive findings. These general results correspond quite well with what one might expect from economic theory. For example, the results yield the expected concavity of the objective function tradeoff curves, and as a region is made more open to trade and labor flows, both gross regional product and industry specialization increase [*15, 16, 17*]. It seems reasonable to conclude that the linear assumptions in the model are acceptable, even though economic relations are, in general, not linear. The linear/nonlinear controversy, often discussed in applications of linear programming models, is not explored here.

The decade 1960-70 was chosen for this study in order to test (using one version of RDAAP) the degree of similarity of the area's actual industry growth (in employment) over the historical period to the model's optimal industry growth.

Although the model was run using 1960-70 data, the results still should prove to be of interest for planning today. Not, of course, the specific *levels* of industry and labor skills chosen by the model, but rather the *type* of industry, and the industry and labor *shares* of those levels. Thus, general interpretations of the results of the model should prove useful for current rural area planning and planning in the near future.

The Study Region

The BMW region (Benton, Madison, and Washington Counties) lies in the northwest corner of Arkansas. The area is a fairly integrated economic unit in terms of labor commuting patterns. U.S. Route 71 forms the industrial hub and transportation axis, ranging from Fayetteville in Washington County in the south, through Springdale, Rogers, and Bentonville to the north. The latter two towns lie in Benton County. Madison County, located to the east, has a comparatively sparse population; its major town, Huntsville, the county seat, has about 1,000 inhabitants. Fayetteville and Bentonville are the county seats for Washington and Benton Counties, respectively.

Geography of the Region

The physical terrain is generally mountainous, with Madison County entirely so, but with northern Washington County and Benton County becoming progressively less hilly as the area begins to merge into the western prairie. The BMW region is located near the geographic center of the Ozarks Mountain region. Average elevation is about 2,000 feet.

The climate in the region is temperate, but with distinct seasonal changes. The weather is quite changeable and temperatures can rise or fall 20 degrees in a few hours. Spring weather is especially turbulent and tornadoes can occur. For Little Rock, Ark., about 150 miles southeast of Fayetteville, the coldest month is January with a normal maximum temperature of 50°F and a normal minimum of 29°F. The warmest month is July with a normal maximum of 93°F and a normal minimum of 70°F. Normal annual precipitation is 48.52 inches [4]. Average temperatures for Fayetteville are slightly lower.

A major resource in the BMW region is the Beaver Reservoir on the White River. This reservoir, lying mostly in Benton County, is the newest of a chain of four reservoirs on this river. The reservoir and its environs are a major recreation area, as well as the source for the BMW region of a very large supply of high-quality water flowing out of the Ozark National Forest. The area is favorably located with respect to natural gas, a raw material of great importance. The BMW region itself has no gas wells, but there are a number of wells and an adequate supply of gas for northwest Arkansas (enough for local use, but not interstate shipment) in the nearby counties of Franklin, Sebastian, and Logan.

Developmental Conflict

Despite a small airport and a two-lane highway (Rt. 71), the mountainous terrain tends to isolate the BMW region from the rest of the country. Accordingly, there is a major conflict over the level of future economic development to be encouraged. This conflict is illustrated by the debate surrounding proposals to build a larger airport in the region and an interstate highway from Kansas City through Fayetteville to New Orleans. Both projects would spur regional economic growth and development.

Conflict over development policy often occurs in rapidly growing areas like the BMW region. One group of citizens feels that there already has been sufficient development, and prefers to close the area to newcomers to assimilate recent growth. An opposing group, primarily representing business and commercial interests, desires more expansion. The question of whether to build the proposed road is still being discussed, while the debate regarding the new airport is focused on its geographical location rather than its construction. The proposed location of the airport lies in the middle of prime (for the area) agricultural land owned and farmed mostly by people of Italian heritage. These people do not wish to see their land and way of life altered as the price for the increased welfare of the whole region. This example of development conflict in the BMW region suggests the inevitability of such disagreement, and indicates the need for cooperation and compromise in both setting and achieving development objectives. Any regional objective sought by one special interest group is likely to be unacceptable to another group. An economic development planning model can be used to exhibit and study such intraregional conflict.

The BMW region's developmental conflict question posed here—rapid versus slow regional growth—cannot be precisely answered by the RDAAP model as presently constructed. It pinpoints a very specific problem whereas RDAAP considers relatively general economic objectives. To handle this conflict, RDAAP would have to be expanded (this requires extensive additional data but presents no serious theoretical problems) to include more industry detail and more noneconomic objectives, such as environmental, welfare, and other nongrowth goals. A problem in considering growth versus no growth in RDAAP is that some of the "givens" in the model—the so-called exogenous variables such as population and labor force growth—should not be assumed as given, but rather should be made alternative *objectives* in the model. Nonetheless, for various assumed levels of population and labor force *targets*, a chosen regional objective can be optimized separately for each target level. The model provides insights into economic tradeoffs among various interest groups within the area relative to general economic objectives.

Development conflict represents a crucial planning dilemma. It is a major problem in any planning situation involving conflicts of interest among various groups of people. It is rarely possible to

satisfy the wants and goals of all competing groups when resources and funds are scarce. In many cases, a given policy can satisfy more than one goal or group at a time, but very often one faction's success comes at the expense or cost of reduced success of another group. Such tradeoffs should be recognized as both possible and likely. They seem to represent an inevitable, and often crucial, dilemma to both the planners and residents of the region. A politician, however, may conceal this conflict in order not to alienate any constituency entirely.

It is the task of the planner to illuminate and quantify these tradeoffs as much as possible so that, through the political process, a well-informed and intelligent decision can be made. It should be based on knowledge of the costs and benefits of various alternative plans; the one plan that is deemed best by the body politic is the one which should be implemented. Analysis of the political aspects of such problems is beyond the scope of this report, but the prospects for tradeoffs among conflicting objectives will be examined.

Other Characteristics

Arkansas is a leading broiler-producing State. Broiler-related activities, including processing, are largely centered near Springdale and Fayetteville. Large manufacturing employers in Benton and Washington Counties include a company that produces plastic materials, a firm that constructs small electric motors, and a firm that manufactures air rifles. These and other manufacturing plants in the BMW region would benefit from the upgrading of the transportation network through reduced transportation costs on both production inputs and finished products. In addition, another large and important facility in Washington County of great economic, cultural, and employment significance is the University of Arkansas at Fayetteville, with an enrollment of about 13,500 students. Madison County, however, has virtually no manufacturing and little service employment.

Fayetteville is rapidly becoming a regional center for primary and secondary medical care. An example of secondary medical care is the access to a computerized axial tomographic (CAT) scanner. Tertiary medical care, like kidney transplant facilities, is not available in the area, although these services can be obtained in Tulsa (Okla.) and Little Rock (Ark.), about 105 and 150 miles, respectively, from Fayetteville.

The BMW region's favorable mixture of climate, recreation facilities, lower cost of living, and relative isolation has attracted a sizable retirement population. The growing numbers of retirees, who tend to prefer a slower developmental pace in order to maintain the quality of life and environmental amenities of the region, will probably make conflict more likely over the economic goals and priorities for the area.

The population of the BMW region has risen significantly over the past two decades, as shown below [*9*, *10*]:

	1960	*1970*	*1978*
BMW Region	101,138	137,299	171,700
Benton County	36,272	50,476	66,400
Madison County	9,068	9,453	11,200
Washington County	55,798	77,370	94,100

Employment in the BMW region has grown from 36,125 persons employed in 1960, 51,507 employed in 1970, to 82,562 full and part-time jobs in 1978.[4] Estimates of per capita personal income for the BMW region (in current dollars) are $1,497 and $3,053 for the years 1960 and 1970, respectively. For 1978, the figure climbed sharply to $6,341 (in current dollars).[5]

Madison County is a "bedroom community" with respect to non-agricultural industries. Its female labor force works about 30 miles away in the poultry-processing industry around Fayetteville-Springdale; the men generally remain at home to operate the small family farms. Most of the commuting from all counties within the BMW region is to the Fayetteville-Springdale-Rogers employment axis on U.S. Route 71 (fig. 1).

A trend toward increased use of managerial and clerical labor, with a corresponding shift to less skilled and unskilled labor, was evident from 1960-70 in the BMW region, Arkansas, and the Nation (table 1). The managerial labor percentage in both years for the region is fractionally above the State average, but a few percentage points below the national average. Clerical labor

[4]Source: see [*9*] for 1960 and 1970, [*11*] for 1978. The 1978 figure refers to the number of *jobs*; the 1960 and 1970 figures refer to the number employed.

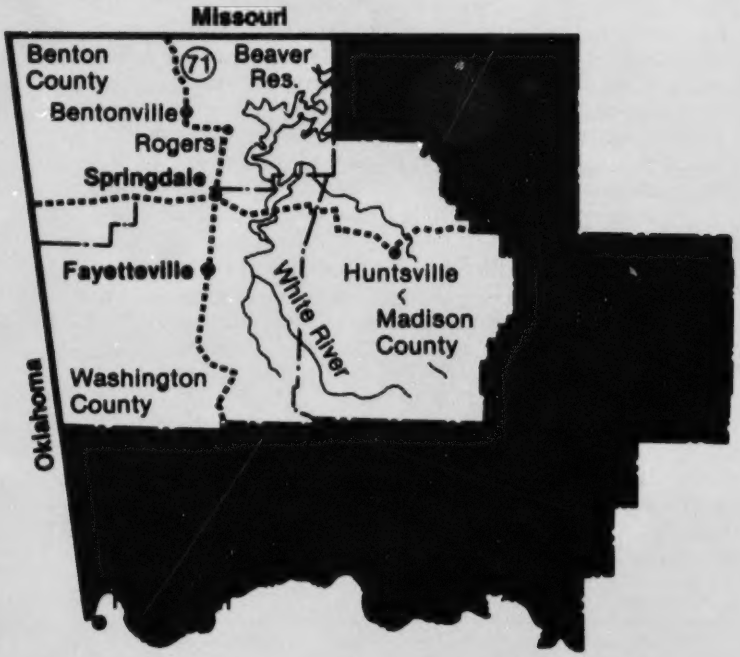
[5]The 1960 and 1970 year figures are income *estimates* calculated by the author, and are the values used in the analysis. The 1978 figure is calculated from a different source [*12*].

percentage is slightly lower in the region than in the State, and sharply less than the national average. Conversely, there is a higher percentage of skilled labor use in the region than in the Nation and in the State. The percentage use of unskilled labor for the region in 1970 lay midway between the State and national percentages, although the differences are not large.

The percentages in table 1 reflect the BMW region's heavier commitment to manufacturing industries (which usually show a higher percentage use of skilled labor) and lesser commitment to the service industries (which usually have a higher clerical labor requirement) than the State or, especially, the Nation.

Figure 1

The BMW Region: Benton, Madison, and Washington Counties, Arkansas



A major portion of the BMW region was designated a Standard Metropolitan Statistical Area (SMSA) after the 1970 U.S. Census of Population. The Fayetteville-Springdale SMSA comprises Benton and Washington Counties. The model used in this analysis was designed for use in *rural* areas with moderate-sized central cities. Running the model for this area from the year 1960 to 1970 provides an opportunity to study how an area can evolve optimally (versus how it actually did evolve) from a relatively rural to a relatively urban status. Historically, population growth has generally been associated with increased urbanization. Such an increase in urbanization is often the indirect result of an economic development program.

The Model

The model used is a rural economic development, linear programming (activity analysis) planning model (RDAAP). The model was applied to the BMW region in northwest Arkansas over the decade of the sixties. The terms "activity analysis" and "linear programming" are used synonymously. Six versions of the RDAAP model were developed. There are 394 columns or activities (including the right-hand-side column but excluding slack activities), and 365 rows or constraints in four versions of

Table 1—Skill levels of employed labor force, 1960 and 1970

Region	Managerial		Clerical		Skilled		Unskilled		Total	
	1960	1970	1960	1970	1960	1970	1960	1970	1960	1970
	Percent									
BMW region	18.5	20.0	8.6	12.6	44.6	40.1	28.4	27.3	100	100
Arkansas	17.0	19.3	9.0	13.1	40.0	38.8	33.9	28.8	100	100
United States	19.6	23.1	14.4	18.0	35.8	33.3	30.2	25.6	100	100

Note: 1970 is the most recent year for which such data are available. Farm "managers" are included as skilled workers in this table and throughout this report.
Source: [*8*, *9*].

the RDAAP model.[6] A fifth model version has additional activities or constraints, and a sixth version has fewer; both of those are discussed toward the end of this report [*21*]. The model is solved for various objective functions for the optimal levels of these activities in the 10th year of growth beyond a base year.

The labor force of RDAAP is divided into four skill levels: managerial, clerical, skilled, and unskilled. Labor activities include four incommuting, four outcommuting, and one skilled-labor training activity, which converts unskilled workers into skilled. The various subgroups of columns and rows form the distinct sectors of the model, which include service, manufacturing, government, agriculture, and export and import.

Service and Manufacturing Sector

The service and manufacturing sector of the RDAAP model is in an input-output format. This format describes the interindustry flows of goods and services between various pairs of industries.[7] It represents what industries buy from and sell to each other. The output of one industry is allocated among the inputs of the other industries or to final demand. These flows are then "normalized" for each industry column by presenting materials and resource requirements per unit of output, where the unit is taken to be $1 million (in 1963 constant dollars). Products not required for intermediate industry or government use are available for final consumption by the residents of the area or for export to other areas.

The manufacturing sector contains 64 industry production activities. Corresponding to each of these columns are 64 commodity rows. The service sector contains 14 production activities and 14 commodity rows.

Each service and manufacturing industry in RDAAP is composed of the sum of two activities: a current production activity and a capacity expansion activity. Since full utilization of industrial

[6]Both the columns and rows are considered "vectors"; the "activities" refer specifically to the columns, "constraints" refer to the rows.

[7]For an industry with more than one type of product (output), the output is classified as a "joint" or multiple output. No RDAAP model, nonfarm industries are constructed with joint outputs, but those in the agricultural sector are. Inputs consist of the materials and labor needed to produce the industry output.

capacity is assumed in the base year, all expansion above the base year level requires investment in capacity. (Agricultural production can be an exception as will be seen later in this section.) The capital expansion activity was constructed with a 10-year planning horizon. However, only 15 percent of the expansion requirement is assumed to be added to current production cost in the model because, as Spiegelman, Baum, and Talbert observe:

> "if capital stock grows at a constant *proportional* rate, the proportion invested in the final year [the 10th year] would be more than 10 percent. Obviously, this proportion would depend on the overall rate of growth of output and capacity, but it can be shown that for annual rates of growth ranging from 5 to 10 percent, the proportion of total capacity to be invested in the final year would be close to 15 percent" [5, p. 14].

Agricultural Sector

The agricultural production sector includes 12 "progressive" farm types, and, for simplicity, combines all "regressive" farm types into one aggregated regressive activity. The terms "progressive" and "regressive" refer to the economic or income class of the farms and are explained below. The farms produce 29 specific farm commodities. There are 29 activities that can import and 29 activities that can export these farm commodities. There are 18 transfer activities that can "convert" 18 of these 29 commodities into 1 of 10 aggregated farm commodity categories. These 10 commodities are at the aggregation level used in the RDAAP manufacturing industries. Sixteen transfer activities convert 13 of the disaggregated farm products, plus 3 pasture categories, into 3 animal feed commodities used in the 7 farm animal-feeding activities.

The progressive farms[8] explicitly embody the technology and organization of the higher income farms (Economic Classes II and III). Economic Class I, the highest-income farm type, is not considered a realistic possibility for the BMW region. The single,

[8]Defined in units of 15 and 25 individual farms, for Economic Class II and III farms, respectively, as defined by the *U.S. Census of Agriculture*.

aggregated regressive activity[9] reflects the lower income farms (Economic Classes IV, V, VI, and part-time) of the type that have been closing down in the study area, releasing land, labor, and capital for other economic activities. One of the functions of the model is to convert regressive into progressive farms, which tends to transfer land from low income to higher income, more successful farms, and to release resources, including labor, for use in the nonfarm sector. For simplicity, the question of land use in nonfarm sectors is ignored.

A commodity produced by the agricultural (progressive) sector must offset any corresponding production loss caused by reduction or cessation of production of that same crop in the regressive sector before any net production of the crop is available for consumption or export. If there remains a "deficit" of that crop, the model debits the region in terms of "foreign exchange" by the dollar amount of that deficit.[10] A deficit in any crop means that the region produced more of the crop in the base year than in the target year.

If, however, a "surplus" crop results, the model can either export it and earn foreign exchange, or the area's food processing industry or other local farmers can use it. Stocks (inventory) as well as flows (amount sold) of agricultural animals are recognized in the model by the inclusion of four farm animal (stock) commodities. Nine activities regulate the proper levels for four farm animal (stock) exports and for five types of animal transfers (to stocks).

Five categories of land are assumed in the model—cropland, three types of pasture, and a total farmland category, which includes a nonproductive, residual component as well as the sum of the four farmland types.

Export and Import Sector

The RDAAP model includes importing and exporting manufactured commodities (not services) to and from the BMW region. For a majority of manufacturing industries (56), there is at least one export activity for each industry whose product can be

[9]Defined in units of 50 individual farms, for the combined Economic Classes IV, V, VI, and part-time.

[10]"Foreign exchange," in the regional sense of this model, refers to all funds originating from outside the BMW region.

exported from the BMW region to the rest of the country. Two export "rings," an inner circle of 200-mile radius from the center of the BMW region, and an outer ring of 200- to 500-mile radius, define the export possibilities.

Exports beyond 500 miles are not included in the model. While some exports, in reality, would be shipped beyond 500 miles, the export constraints needed for such an export ring can be ignored. Their omission does not affect the model results excessively because of the use of parametric programming which simulates higher (constraint) levels of exports.

Fifty-six industries can export manufactured products to the inner ring, and 45 of those can also export to the outer ring, for a total of 101 separate manufacturing export activities. Transportation costs are assumed higher (and net prices received less) for a commodity shipped to the outer ring than to the inner ring. There is a separate commodity row corresponding to each manufacturing export activity in each export ring.

All manufacturing industries except one—stone and clay mining and quarrying—have an import activity; there are 63 such import activities. This permits the region either to import these commodities or to produce them locally. All commodities assumed not producible in the BMW region (i.e., not among the production activities in the model) but required by the area, are imported by the model via fixed import coefficients in the current and capital production activities and in the final demand vectors for government and consumption spending.

Government, Consumption, and "Foreign Exchange" Sectors

Government enterprises, private consumption, and government final demand targets are represented by three activities. The "foreign exchange" sector consists of four activities: one records a surplus of foreign exchange if such a surplus results in the BMW region current account; another records a deficit if a deficit results on current account; a third records a deficit on capital account;[11]

[11]In other words, foreign exchange requirements (for those products and services assumed not producible in the BMW region) are considered as two different row requirements in the model—one for current production activities, another for capacity expansion activities. Since all exports are allotted to the current account row, there is no possibility but deficit for the capital account row.

a fourth represents the outflow of profits from the region. Investment into the region is recorded in each individual manufacturing and service production activity. Depreciation charges on the capacity expansion activities are added to the inputs for the corresponding current production activity. Depreciation charges on the imported inputs for the capacity expansion activities are an exception in that they are allotted to the foreign exchange row on capital, not current account.

Regional Objectives

The regional objectives explored in this study include maximizing:

Regional balance-of-trade surplus.

Regional balance-of-payments surplus.

Gross regional product.

Gross regional product, assuming that some incommuters become immigrants.

Local value added.

Local aggregate wage bill.

Local employment.

Regional private industry aggregate profits.

Regional industry-wide profit rate-of-return index.

The term "local" means that wages (or employment for the local employment objective) are included only for BMW region residents working locally. Wages (or employment) for incommuting and outcommuting labor from the BMW region are excluded from these totals.

Regional balance-of-trade surplus is defined here slightly differently from its usual definition—that is, net regional exports minus imports, but here including also the net receipts of outcommuting labor wages above those of incommuting labor wages. Regional balance-of-payments surplus adds to this the net

flow of investment and profits. Gross regional product is also defined somewhat differently: consumption plus investment plus government plus exports minus imports, but including also net wages of outcommuters above those of incommuters. These net commuting receipts were included in these regional objectives because of their substantial size.[12]

Local value added measures the value of all industry output minus the value of all inputs, except labor. Incommuting as well as outcommuting labor wages are excluded. Levels of value added and gross regional product differ from each other in the model (in theory they should be identical) because the former excludes outcommuting labor wage.

Local aggregate wage bill is the sum of industry wage totals, again excluding wages for both incommuters and outcommuters. Local employment is measured as the sum of industry employment levels, excluding incommuters and outcommuters. Regional aggregate profits for private industry are calculated by summing the profit portions of value added for each industry. The regional industry-wide profit rate-of-return index is a weighted sum of the individual industry profit rates of return multiplied by the corresponding industry production levels in an optimal model solution. The index is measured in units of $1 million, as are all other objective functions except local employment (generally measured in units of 1 million hours worked).

Optimal values of these various objectives cannot be realized simultaneously. An important part of this study shows the extent to which some economic objectives are sacrificed when others are maximized. Tradeoffs among alternative objectives are an important part of the planning process. Given an objective, the RDAAP model solves for the most efficient way to reach that objective, subject to economic and technical constraints.

Other Characteristics of the Model

The RDAAP model is of a marginal or incremental form.[13] It takes as given the production levels of the base year, 1960, and

[12]The question of the sizable amount of labor outcommuting observed in most versions of the RDAAP model will be discussed in several places in this report.

[13]Except for one version of the model (Total Model) which will be discussed later in this report.

measures the increases from those levels to the levels in the target year, 1970. All targets and regional resource availabilities are similarly defined in terms of increases; that is, the target year levels minus the base year levels. The base year production is called the "old sector"; the increases called the "new sector."

As a simplifying assumption, no production levels (except for agriculture, as explained earlier) are assumed to decline over the planning period; they either increase or remain at base year levels. Similarly, resource availabilities (e.g., labor force by skill level) are assumed only to increase.

The model covers 10 years, but considers explicitly only the 10th or final year. All capital investment required for expansion, both public and private, is assumed to be constructed and installed over those 10 years, with 15 percent of that total invested in the final year. No specific consideration is given to the yearly pattern of growth except for (1) the amount of capital invested in the terminal year, and (2) the targets to be met by that last year such as consumption (i.e., implied per capita personal income) and government spending.[14] The technology and labor productivity assumed for these production increases are embodied in the input-output coefficients of the production activities.

An exception to the assumption of unchanged production and the labor usage in the old sector of the incremental forms of RDAAP are: (1) regressive agriculture which is converted to a progressive farm configuration, presenting the possibility of reduced production of particular crops; and (2) assumed technical change in the old sector, made possible by investing the exact amount of capital in the old sector needed to raise that sector's labor force productivity by the same percentage as the targeted increase in per capita income for 1970.[15] This second process results in a "release" of labor from the old sector to the new enabling the remaining workers in the old sector to produce the same total product as in 1960. That is, the old sector absorbs

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[14]These are the fixed *targets* (i.e., using equality constraints) of the model, but they are not the objective function. In one RDAAP model version (Adjusted Planning Model), these targets are not fixed, but vary depending upon the levels of income earned and taxes collected.

[15]It is assumed that, all things being equal, for real per capita income to rise in the old sector, labor productivity in that sector must be increased by the same percentage as the increase in real per capita income.

capital from the new sector, increases its productivity, and releases some labor to be absorbed by the new sector. This property of the model is discussed in detail in a later section.

Basic Model

The six versions of the RDAAP model are similar except for changes in crucial assumptions with respect to labor force, taxes, consumption, etc. Of these variations, only two versions are explored here in detail. The first, the Basic Model, ascertains whether the model's endogenous variables (industry employment levels, labor usage by skill level, etc.) can predict actual regional growth results and it provides insights into the planning function.

The income target of the Basic Model is the actual increase in per capita personal income over the sixties for the BMW region. Labor availability is equal to the growth over the decade in employed labor force, by skill levels, existing in 1970.[16] Other exogenous (not determined by the model) parameters are taken to be those that existed in 1970.[17] Thus, rather than calculating estimates for the exogenous variables in 1970, based only on information known in 1960, actual 1970 data are used to give the model the best possible chance to predict accurately the endogenous variables. Thus, the question can be addressed: Even if the planner had near "perfect" projection techniques for exogenous data such as population, growth in labor force by skill levels, increase in per capita income, and so on, would the model's endogenous variables predict accurately which BMW region industries grew over the decade?

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[16]The labor supply also includes "released" labor resulting from both investment and technological advance (i.e., due to labor productivity increases) over the 1960-70 decade for the 1960 labor force of the BMW region economy, including the agricultural sector. The small level of labor incommuting in the model adds to the labor supply as well.

[17]The manufacturing sector production "core" of the model matrix, however uses 1958 data (1963 data for the service sector) at a detailed level from the "work sheets" used to construct the national input-output matrix of the U.S. Dept. of Commerce. These data are "ruralized" in that industries at the seven-digit level, and believed to be predominantly rural, are used to construct the industry activities. Thus, the industries in the RDAAP model, at approximately the four-digit SIC level, ar assembled from base data of a more disaggregated form.

Adjusted Planning Model

The second version of the RDAAP model receiving emphasis in this report is the Adjusted Planning Model. It is similar to the Basic Model except for certain crucial assumptions. In this version, I used the Stanford Research Institute (SRI) methodology to estimate labor skill supplies, rather than use the actual (increase in) regional labor skill supplies for 1970 as in the Basic Model.[18] The SRI technique uses State labor force participation ratios (targets) to determine the increase in the regional labor force available, and uses State high school graduation rates (targets) to determine the labor skill breakdown of that labor force increase.

Most of the other exogenous data, however, are the same as for the Basic Model. These latter data are therefore somewhat different than if they had been based on projections using base year information only. This simplification should not hinder the study of this version's capabilities.

Several other improvements are included in the Adjusted Planning Model. For example, in the Basic Model results, government spending (Federal, State, and local) far exceeds total taxes (Federal, State, and local) collected. While small deficits may be reasonable for a growing area, the large deficits observed seem excessive. For simplicity, a balanced budget was required in the Adjusted Planning Model.[19] Government spending is limited to taxes collected.

Consumption expenditures in the Adjusted Planning Model were set equal to the total wage bill (minus personal taxes and savings) earned by the region. Rather than targeting the personal per capita income for the region, and tying consumption to that target, consumption growth is limited to a percentage of the aggregate wage bill actually earned. In the Basic Model, consumption is targeted irrespective of whether the region earns enough in wages to support that consumption without being subsidized (implicitly) from outside the planning area. A similar

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[18]The labor supply of the Basic and Adjusted Planning Models, however, also include the "released" workers from the old sector, a concept not in the SRI formulation. See footnote 16.

[19]Note, however, that one could vary the deficit (or surplus) in the model to whatever level seemed acceptable.

income target assumption leads to the level of the government expenditure target in the Basic Model.

Labor transfer activities added to the Adjusted Planning Model permit some "conversion" (assumed costless) of labor from one of the four skill categories into another. The levels of conversion permitted are small compared with the total supply of labor by skill level, and are limited to those levels and those conversions that might be assumed possible without retraining programs. These transfers can be assumed as virtually costless in terms of the regional resources that might have been required, such as educational facilities, teaching personnel, etc. For example, rather than assuming all, and only, female high school graduates to constitute the clerical labor force (as in SRI's methodology), the Adjusted Planning Model assumes that a percentage of these graduates can become managers. This percentage is determined by dividing the number of female managers in Arkansas in 1960 by the number of nonenrolled (not currently in college, etc.) female high school graduates in the State in 1960. This portion of the regional female labor force is included in the clerical labor supply, but can be transferred to the managerial labor supply at zero cost.

These transfer activities partially help reduce the unrealistic rigidity of labor skills in the model. This increases the number of possible labor supply combinations by skill level. The assumption of *fixed* supplies of nonreproducible and nontransferable resources is associated with most linear programming models.

Selected Model Assumptions

In this section, some observations and explanations will be made on selected aspects of the RDAAP model that pertain to almost all model versions. Only the most crucial features which differ from the most recent SRI model formulation (which forms the core of the RDAAP model) will be mentioned here. Discussion of these changes will help the reader to understand some of the assumptions underlying the entire analysis.

Increase in Labor Productivity: Old Sector

The RDAAP model includes a mechanism that increases the labor productivity of the base year (1960) labor force. This topic was briefly discussed in the last section. Except for the Total

Model version, the RDAAP model is concerned only with target-year (1970) *increments* above the base-year (1960) levels.

In both the SRI and RDAAP formulations, the income target applies to *all* residents of the multicounty study area, not just to the *increase* of population and labor force between the base and target years. However, if one limits the model's labor supply to only the increase in labor force between the base and target years, the model becomes flawed. Then, the increase in the labor force would produce income not only for themselves and their families, but also to satisfy the targeted income increase for the remaining (base year) population in order to bring the latter incomes up to the overall per capita income target. Such a requirement is unreasonable. The labor force of the old sector should earn and produce its own increase in income by means of increased labor productivity. Accordingly, some information from the old sector must be included in the incremental model.

To accomplish this, the old sector absorbs capital from the new sector in order to raise its productivity, and then "releases" a portion of its labor force to the new sector.[20] The size of the required lump-sum investment should be sufficient to increase the productivity of those workers who remain in the old sector after this portion is "released," such that: (1) the remaining old sector workers produce exactly the same level of gross output as was produced by all workers in 1960; and (2) their increase in labor productivity equals the targeted increase in per capita personal income. (Note that the productivity and technology level of the new sector—which includes only production increases—is determined by the fixed coefficients of the RDAAP model input-output matrix.)

To calculate the required size of the investment needed for the old sector, I used a Cobb-Douglas production function, which includes a factor representing a "natural" increase in productivity due to technological advance, increased labor force education, and so on.[21] To keep all production increases only in the new sector,

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[20]A much more complicated, and perhaps more accurate, solution could have been devised by disaggregating many or all of the sectors and industries in the base year region, but such a strategy was not developed in order to limit the scope of the work required.

[21]A Cobb-Douglas production function involves capital, labor, and technical change.

the model "releases" a percentage of the old sector (original labor force) workers to the new sector, thus augmenting the labor supply.[22] This percentage in the RDAAP model (all model versions other than the Adjusted Planning Model) is 1.0 - (1.0/1.553) = .356 = 35.6 percent, since the targeted increase in per capita income is 55.3 percent over the planning decade.

Then, since all variables in the Cobb-Douglas function are assumed to be known except for the required increase in the capital stock of the old sector, the equation is solved for this increase. An old sector investment "industry" is then created, and included in the model to represent the lump-sum investment required. The lesson for the planner is that even in an incremental model, the old sector cannot be totally ignored.

Government and Consumption Sectors

Government is divided into two sectors: government purchases, the larger sector; and government enterprises. The latter is included as a private industry in the model matrix. The former embodies not only local, but also State and Federal purchases.

Based on the target for per capita personal income, a government expenditures target (for all but the Adjusted Planning Model) is created. As a simplifying assumption, a national average government spending pattern for combined local, State, and Federal procurement is assumed for the BMW region. The size of these purchases is determined by the combined local, Federal, and State tax increase estimated to be commensurate with the size of the targeted increase in per capita personal income. It is assumed that the total increase in government spending for the area will exactly equal this *estimated* tax increase. For all governmental purchases of goods and services producible in the region (i.e., the model industries), such goods will be produced locally only if the model solution deems it optimal.

The flaw in the above government (and tax) *target* is that there is no internal model mechanism to ascertain whether such a target

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[22]RDAAP model production (i.e., new sector) represents all, and only, the increases in regional production. That is, except for the agricultural sector, no decreases in production for the BMW region, below 1960 base-year levels, are assumed.

is reasonable or attainable. That is, does the model generate endogenously the increase in taxes exogenously targeted? Accordingly, a "taxes" row is added to the RDAAP model. In the Basic Model version, this row represents only a "feasibility check" on the level of government purchases. It does not actually constrain the level of government spending to the model's "internally" earned level of taxes, but merely "lists" the resulting deficit (or surplus) of internally earned taxes in the model.

The Adjusted Planning Model, however, prescribes a balanced budget: the level of total government spending is constrained to equal the total level of taxes accrued. In all versions other than the Adjusted Planning Model, any failure of the exogenously determined tax increase (based on the targeted increase of per capita income) to equal the actual endogenous tax increase, will be, at least partially, a result of the model's failure to reach the targeted per capita personal income increase.[23]

The per capita personal income target may not be reached, but the consumption increase target (based on this income target) is always achieved in the Basic Model. The model "meets" that portion of consumption above its endogenously earned income with (implicit) subsidies from the rest of the country. The government deficit is similarly subsidized from outside the BMW region.

A feasibility check is introduced for the level of targeted consumption spending in the Basic Model; it is similar to the check on government deficits. This becomes an indirect check on the targeted increase in per capita personal income in the Basic Model. In the Adjusted Planning Model, consumption is limited to the exact level of the model's internally earned wage bill and other income, that is, consumption is limited to the increase in per capita income actually achieved by the model.[24]

In versions of the RDAAP model (variations from the Basic Model) in which income and consequently government and consumption spending targets are raised successively, the results show that these targets are not met by increased production but

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[23]The model's internally determined *ratio* of the endogenous tax increase to the endogenous increase in per capita income could also vary from the projections and, thus, be a further contributing factor to the difference between exogenously estimated and endogenously accrued taxes.

[24]More precisely, consumption represents a fixed "average propensity to consume" percentage of these wages and other income.

by increased subsidies.[25] Thus, the setting of income targets without some knowledge of the region's productive capacity—that is, without some "prior run" estimate of the model solution—may result in infeasible income and tax targets.

Other Regional Income

The RDAAP model includes an activity estimating the net level of "other income" in the BMW region. The SRI model earns only that portion of personal income consisting of wages and salaries, and implicitly includes proprietor income. In RDAAP, however, income includes, in addition, payments from interest- and dividend-bearing assets and Social Security transfers (minus Social Security taxes) which together can be considered as net nonwage income. Such additional income, when added to wages and salaries, increases the total income and consumption levels.

Planning Insights: General Observations From RDAAP Results

This section and the following summarize some of the important RDAAP model results. Both sections address this question: What has the model yielded that might prove useful to rural multicounty area economic planners and officials? This section is less detailed and describes the more general RDAAP model results common to most model versions. The following section depicts results more dependent upon specific (alternative) versions of the model and emphasizes more the detail and specific numerical results. Readers who wish a more thorough understanding of the RDAAP model will probably want to read both sections. Those who desire a less thorough, although sufficient understanding of the main results of the RDAAP model, can omit the second section.

When implementing any of the six versions of the RDAAP model, what common planning insights arise, and of these, which seem most crucial for area planners? That is the question addressed in this section.

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[25]The Adjusted Planning Model does not include targets for income and taxes and considers only those income and tax levels actually earned internally (i.e., actually attainable) by the model.

Objectives

The choice of regional objective greatly affects the optimal solution to the model. The nine area economic objectives used in RDAAP were listed earlier in this report. Six of the objectives (balance of payments, balance of trade, gross regional product, wage bill, value added, and employment) are used in all six versions of RDAAP, including both the Basic and Adjusted Planning Models; three objectives (profits, rate-of-return index, and gross regional product with labor immigration assumed) are used only in the Adjusted Planning Model.

Perhaps the simplest objective considered is the maximization of regional balance-of-trade surplus. This surplus is defined here to include net wage income of outcommuters above incommuters. This objective is similar to minimizing a foreign exchange deficit, an important consideration and one often used in national economic models in which foreign exchange is considered the most scarce production resource. However, unless foreign exchange really is the scarcest factor, such a strategy can be considered a mercantilist notion of development.[26] Therefore, it is probably, in general, too narrow an approach to the development question, especially for a region within a country. The historical course of development usually shows that nations, and regions within a country, are debtors in their early and middle stages of growth. Thus, an objective whose concern is to minimize this debt can be considered inferior to the ultimate goals of the region.

The original SRI model, the Kentucky Model, considered only one regional objective—minimization of a "foreign exchange" deficit, Spiegelman [7] believes this to be the preferred objective, given proper specifications for exports and imports (constant prices and fixed export limits), and for wages and interest rates. He feels this objective will lead to a solution approximating the perfectly competitive situation. Nonetheless, planners should consider a whole range of possible objectives (economic, environmental, political, health, etc.) for their regions, not just the perfectly competitive one. Only regional macroeconomic objectives, however, are explored here.

[26]Mercantilism tends to emphasize an area's accumulation of gold and silver bullion reserves and favorable trade balance *for its own sake*, rather than for some ultimate purpose, such as improving the welfare of the country's citizens.

Objective Function Values. The values of the objective functions will be compared both when a function is used as the objective, and when it is used as a constraint for another objective. However, the right-hand-side constraints for these rows are chosen so that they cannot be binding. They serve instead as accounting rows. There are two exceptions to this: First, the balance-of-payments surplus is constrained to be nonnegative for all regional objectives (except for the Adjusted Planning Model); second, in the tradeoff analysis between objectives to be discussed later in this report, one objective is optimized while the other is varied parametrically. This section will present a more general interpretation of the results. Selected details will be presented in later sections when discussing the various versions of RDAAP (especially the Basic Model).

Most of the aggregate and detailed solution results from the application of the RDAAP model to the BMW region tend to fall into two groups with respect to six of the objective functions. Among the six objective functions of the Basic Model, maximizing balance-of-trade surplus, balance-of-payments surplus, and gross regional product are objectives that lean more toward the interests of capital or management.[27] Conversely, maximizing the local value added, the local aggregate wage bill, and local employment are objectives more preferred by labor. Although this division of the six objectives into capital or labor orientation can be understood almost intuitively from the definitions of the objectives, it is confirmed also from the model output. In general, the capital-oriented objectives yield both higher aggregate regional profits and industry-wide profit rates-of-return on capital investment, and lower aggregate local wage bills than the labor-oriented objectives.

The values of the objective functions can be considered for our purposes as regional macroeconomic variables. For example, total local employment for the region would be labeled as an aggregate or macroeconomic variable; total employment in a specific four-digit SIC manufacturing industry in the region, a disaggregated or microeconomic variable. There is more variability among the results for all six objectives for the regional microeconomic

[27]The maximization of regional profits, profit rate-of-return index, and gross regional product (immigrant version) of the Adjusted Planning Model would also be included among this capital-oriented group, but the results for these three objectives are not discussed here.

variables—such as, for example, the type of manufacturing industry selected—than for the regional macroeconomic variables. This increased variability tends partially to obscure the differences (with respect to microeconomic results) between the capital- and labor-oriented groups of objectives. The division is less distinct than for the aggregated variables. Similarly, there is more variability in microeconomic than macroeconomic variables *within* each of the two groups of objectives.

Thus, similar levels of aggregate regional variables can mean quite different choices of industry, and different relative consequences for special interest groups that may align themselves with certain types of industries. The preferred solution, or that mix of industries and use of local resources (including labor) that is best for the region, depends upon the planner's (that is, political community's) criteria for "best." Or, more generally, it depends on a political resolution of internal conflict as, for example, in the airport location problem noted earlier.

Employment Subtotals. While levels of employment among individual industries vary quite widely among all six objectives, employment totals for aggregated subgroups of those industries vary much less. These employment subtotals fit into the same two-group pattern as above: capital and labor orientation. Since the Basic Model yields employment outcomes fairly representative of all RDAAP model versions, they are described here.

The employment subtotal for manufacturing is only slightly higher for the labor-oriented objectives than for the capital-oriented ones. For individual manufacturing industries, the variation between (and within) the two groups is more pronounced. In addition to the more general interpretation of the grouping of these results—their capital and labor orientation—there is another possible explanation. The first three regional objectives all tend to minimize the use of "foreign exchange," while the latter three do not (except to insure that the regional balance-of-payments surplus does not fall below zero). For both of these reasons, results would be expected to differ between the two groups.

A comparison among objectives of employment levels in government and service industries is not especially meaningful because of the simplifying assumptions used in the model. Variations in the output and employment levels of the individual service

industries occur only because of shifts in regional demand, and are not due to variations in external demand since no services are exported. This assumption for services is reasonable for a small metropolitan area.

In all model versions but the Adjusted Planning Model, the level of government employment and the level of government activity are set at fixed targets. The employment target is based on the actual increase in government employment in the BMW region during 1960-70; the government activity level is derived from the target for increased taxes. This tax increase depends on the required increase in personal income per capita.

Optimal employment levels in the agricultural sector vary among the alternative objectives; different types of farms are selected in the various solutions. For the capital-oriented objectives, only general farms come into the solution, while for the labor-oriented objectives, both general and poultry farms are chosen. For two of these labor objectives—maximizing the local wage bill and the local employment—employment in poultry farms becomes substantially larger than in general farms, a situation resembling that of the actual BMW region.

Conflicts Between Objectives. With the RDAAP model, the planner can ascertain the best set of industries corresponding to a particular economic objective. These alternative objectives, however, can be conflicting in that a gain in one may result in a loss in another. Only pairs of objectives are studied here. The results show tradeoffs to be more prevalent betweeen a capital-oriented and a labor-oriented objective than between any two objectives in either group. The RDAAP model can quantify the range and extent of tradeoffs between any pair of objectives.

The tradeoff concept may be better understood by recalling the production possibilities analysis of economic theory ("guns versus butter") as shown in figure 2. Curve *a* represents an economy at a given technological and resource level (including labor) with all resources fully employed. For such an economy to produce more butter (nonmilitary), a reduction in gun (military) production is required; and conversely, more gun production is possible only with less butter production. To produce more of *both* commodities requires an increase in labor and other resources, technological advance, a freer flow of labor and goods among regions, or

any combination of these. Such an expansion in the economy is represented by a shift from curve *a* to curve *b*.

Using the RDAAP model, I computed an example of tradeoff analysis for the BMW region (figure 3). In curve *a*, the regional balance-of-trade surplus worsens with increasing levels of local employment. Because of the definition of the trade surplus in this

Figure 2

Production Possibilities Frontier for an Economy (Hypothetical)

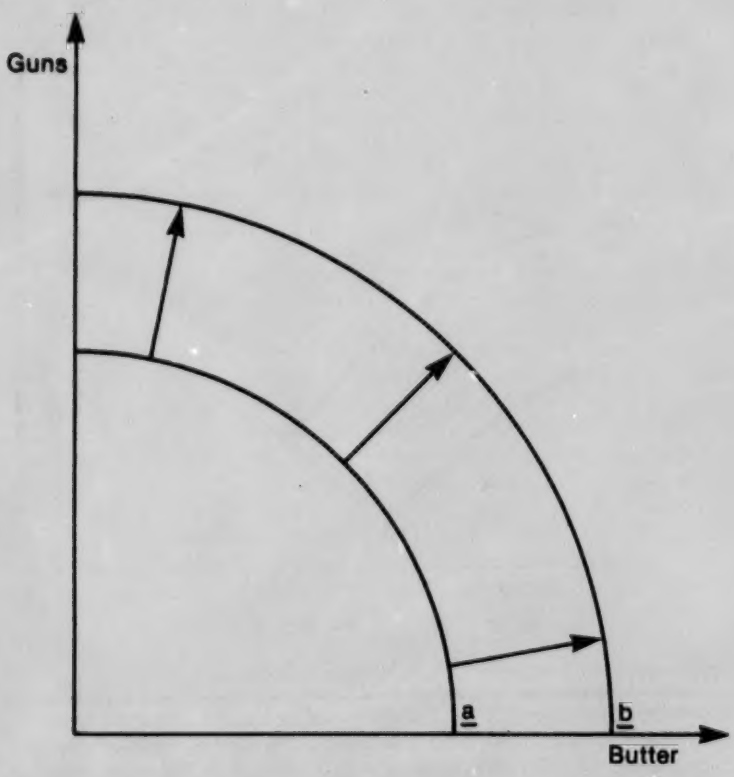
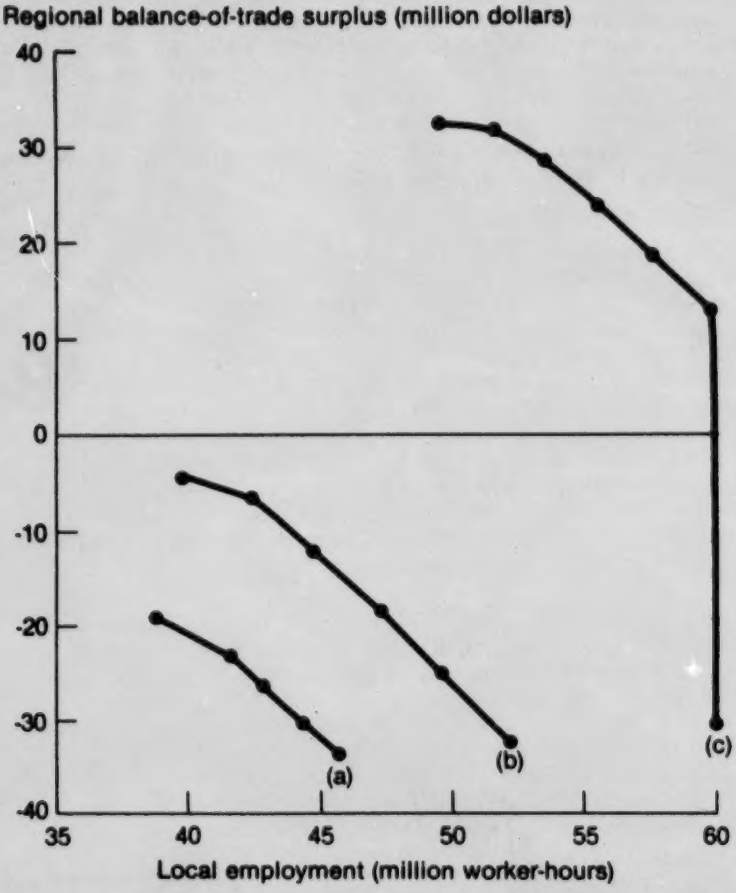


Figure 3

Objective Function Tradeoff Curve

Regional Balance-of-Trade Surplus as Objective Function, Local Employment as Constraint Row,[1] BMW region, 1960-70



[1] With regional balance-of-payments surplus constrained to zero or above.

Movement from a to b to c shows successive increases in both export and labor incommuting constraints, representing an increasingly open economy with respect to commodities and labor.

model—net commuting wages are included—this reduction represents the loss of (net) commuting wage surplus in addition to a reduction of exports minus imports. The movement from curve *a* to *b* to *c* represents successive increases in the commodity export and labor incommuting limits. That export markets can absorb large increases (at fixed export prices) is assumed possible in the model.[28] If the planning area is quite small in relation to its export markets—and this is the case for most small, rural multicounty areas—this assumption seems warranted. The more general question of a planning area's ability to attract *any* export industry to locate in the area is briefly explored in the next subsection.

The expansion in export markets and labor availability can be interpreted as representing a more open status for the region with respect to the rest of the country. That is, it simulates a freer trade in commodities and movement of labor. As a result, greater industry specialization and increased regional production can occur. A shift from curve *a* to *b* to *c* results in greater curvature (less linearity) in the tradeoff (fig. 3). That is, in more open regions, the expected diminishing rates of marginal substitution between the two goals become even more pronounced. For a region moving closer to an endpoint on the curve, to raise local employment requires the loss of increasingly larger units of the balance-of-trade surplus. Also, as the region becomes more open, the range of tradeoffs is much larger.

The lesson to be learned is that for more open regions, the opportunity cost of optimizing a *single* regional objective can be relatively large. Planners may rather seek a solution near the middle of such curves where opportunity costs are smaller and where a compromise between competing interests is likely to be reached. For more closed regions (e.g., curve *a*), the opportunity cost is fairly constant (that is, the tradeoff curve is more linear) and the range of tradeoffs is more narrow, so that the problem in using an unconstrained single objective is relatively less than for an open region.

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[28]Export prices are not completely rigid in the RDAAF model, since a two-step demand function is assumed; the outer export area has lower realized export prices than the inner. Adding more steps would simulate a more accurate representation of reality. However, including export demand as a continuous function (even if linear), would lead to a quadratic, not linear, programming formulation.

Figures 2 and 3 represent the tradeoffs involved when considering only two objectives. When more than two objectives are important, tradeoff curves should be constructed in more than two dimensions. Such a technique could represent the full range of tradeoffs for all regional macroeconomic goals which are considered important. Also, although not shown here, the variety of industry, and differing resource and labor requirements (by skill level) represented by each point on a tradeoff curve, could be presented. Moving from point to point on the same curve could reveal changes in the mix of such microeconomic variables. As a hypothetical example, such movement might reveal the reduction in employment of unskilled labor and an increase in employment of managerial labor. This reduction in unskilled labor could be considered the cost of increasing the employment level of managerial labor.

Other tradeoffs between regional objectives were studied, but no discussion of them will be made here, except to note that the largest-sized tradeoffs tend to be between the trade surplus and gross regional product objectives on one hand, and the employment, value added, and wage bill criteria on the other. Conversely, the tradeoff range between any two objectives within either group is quite limited. These results, too, can be interpreted in terms of the capital and labor orientation discussed earlier. If the former objectives represent more the interests of capital or management, and the latter the interests of labor, the large tradeoff ranges between them tend to highlight the longstanding conflict between the two groups. The tradeoff concepts presented in this subsection are explored in more detail in [*15, 16, 17*].

Attracting Industries to the Planning Area. Depending upon which of the alternative objective functions is chosen, the optimal composition of industries will vary. A detailed examination of how a regional planner or Chamber of Commerce could "induce" groups of industries to locate in the area in order to meet the chosen objective is beyond the scope of this bulletin.

The RDAAP model has been augmented, however, by the addition of a regional objective that maximizes total regional private profits. This objective can lead to a group of industries that is relatively more attractive from an outside (or local) investor's point of view, than groups of industries corresponding to other regional objectives. That is, it is assumed that the solution

resulting from the profit maximization objective yields industries more profitable *as a group* and, thus, relatively more attractive to investors.

Similarly, the objective function of maximizing the industry-wide profit rate-of-return index yields an industry solution which might also be relatively attractive to potential area investors. This second objective, however, has not proved as potentially useful as the first.

When these two objectives are not used as objective functions, and are included as nonbinding constraints, their row values help determine the relative attractiveness of industry groups to investors. The result of these comparisons is that the capital-oriented objectives result in regional industry mixes that are more profitable as a group than the industry mixes associated with the labor-oriented objectives. For example, in the Basic Model, regional profits range from a high of $29 million for the gross regional product objective to a low of about $25 million for the local wage bill objective. Planners must be aware that it may be relatively easy to attract industries to meet an objective when expected profits are high, but that the industries required to meet another objective for which expected profits are lower might not be as interested, as a group, in locating in the area.

A third investors' calculation was made as well, yielding a regional industry-wide profit rate of return on investment (total regional terminal-year profits divided by total regional capital invested over 10 years).[29] For the Basic Model, the rate of return ranged from a high of 15.2 percent for the trade surplus objective to a low of 12.3 percent for the local wage bill objective. The percentages for the capital objectives were consistently above those for the labor objectives. All things being equal, one would expect higher such ratios to be preferred by investors over lower.

How can this third investors' calculation be further interpreted? According to Spiegelman, minimizing the regional "foreign exchange" deficit should yield results most closely related to those of perfect competition [7, p 144]. Therefore, the results for the regional industry-wide profit rate of return on investment seem

[29]The regional profit rate of return on capital investment is not calculated as a model row, but rather from the results of the optimal solution to the model and, thus, cannot be used as an objective function.

reasonable. That is, the industry-wide rate of return is highest for the maximization of the regional balance-of-trade surplus, which is a similar objective to that of minimizing the use of foreign exchange.

In competitive equilibrium, the average value product of each factor of production is higher than it would be under any other alternative economic system. Similarly, one would expect each average value product in the linear programming competitive solution to exceed that obtained from any other linear programming solution. Factor remuneration (for example, "wage" for labor, and "profit" for capital) equals both marginal and average value product in such equilibrium. If capital (i.e., 10-year investment total) is considered a factor of production, and profit (i.e., 10th-year total regional profits) its factor payment, the ratio of the latter to the former—the industry-wide profit rate of return on investment—should be largest for the competitive solution of the regional model. (The topic of attracting industries to the planning area is further explored in [*22*], although a different version of RDAAP—Adjusted Planning Model was used, in which the "competitive solution" interpretation cannot be made.)

In short, it seems reasonable for investors to be attracted to industry groups that yield higher regional profits, given an adequate industry-wide profit rate of return on investment. If future decades beyond the planning decade of the model are considered, it may make sense to focus on regional profits totals rather than on industry-wide rates of return only. For example, a larger area profit (or rate-of-return index) level, even with perhaps a lower profit rate of return for the area, may portray a more accurate picture of investor preference. The mix of industries corresponding to such a solution may be easier to attract to the area, reducing the financial burden of regional tax incentives, infrastructure development, and so on (supply side of growth) needed to induce these industries to locate in the planning area.

But this is as far as this analysis can go because of the absence of a true interregional mechanism in the model. The RDAAP model is intraregional, not interregional, and simultaneous determination of optimal industry groups among all regions is not possible with this model. Hence, no conclusions can be made from the model with respect to comparisons of these three profit criteria among regions.

A related question of whether regional economic growth comes at the expense of other regions is also ignored in this analysis. This seems reasonable because the planning region is assumed to be very small compared with the Nation as a whole.

Industry Economic Characteristics

For RDAAP or other similar models, the solution results for industry or exports may prove insufficient for the regional planner. Consider the manufacturing sector in the RDAAP model, which contains only 56 individual export industries from which the model is to choose. Most of these industries are at approximately the four-digit SIC level, only 56 of the total of about 450 four-digit SIC manufacturing industries are included in the model.

An optimal solution, given a particular objective function, tells planners which industries are best. But how can planners state that a particular industry (or group of industries) is best if they consider only about 12 percent of the possibilities? Yet expanding the model to include most of the possibilities would be prohibitively costly, time consuming, and unwieldy.

At least 50 percent of the manufacturing industries that actually increased employment in the BMW region during the 1960-70 decade were not included among the 56 RDAAP model (SIC) export industries. If one views industries only by their SIC number, or product type, such a result might limit the value of the model for area economic planning.

Regional planners, however, may view the problem in a different light. They are more interested in the economic characteristics of the export industry selected by the model's optimal solution than the specific SIC number. They prefer information on whether the industry is light or heavy, capital or labor intensive, clean or dirty, high or low wage, and so on before they (representing their political jurisdiction) select it. For example, a chicken-plucking plant, proposed by industry executives, was rejected by a community in Oklahoma because it had an undesirable characteristic—an unpleasant odor.[30] This also reveals another consideration—

[30]Such a characteristic (environmental) is not available in the RDAAP model as it presently exists, nor is it among the industry characteristics studied here, but a separate research study could add such a consideration to the model.

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specific industrial plants, not a representation of an aggregated four-digit SIC code classification, locate in an area. The four-digit SIC classification (defined by product type) is broad with respect to product mix, plant and firm type, input-output coefficients, and other industry economic characteristics. Planners cannot know whether a plant is "representative" of a selected (optimal) four-digit SIC category (with respect to the "average" value of the coefficients or economic characteristics of that SIC over all plants or firms comprising the SIC category). This problem is a manifestation of the industry aggregation problem, common in all economic modeling.

Thus, industries should be considered not only by the type of product they produce, but also by their industrial economic characteristics such as capital/output ratio, capital/labor ratio, profit rate of return, value added/labor ratio, and so on. Rather than asking the linear program to select only which products should be manufactured, it is sometimes more fruitful to ask what industry characteristics contribute most to achieve the program objective.

Multiple Regression. Planning insights into critical economic characteristics can be obtained by use of multiple regression analysis on the manufacturing export industry valuations (that is, the "shadow prices" and "reduced costs" in linear programming terminology).[31] This topic has been described in detail in [*18, 19*].

The results for eight of the nine objective functions of the Adjusted Planning Model—excluding gross regional product (immigrant version)—are presented here. The method used is as follows: for a maximization objective such as for gross regional product, the export commodity shadow price measures, all other things being equal, the increase in value to the region (in terms of the objective function) of an extra unit ($1 million) of that export. "Negative" shadow prices, labeled reduced costs (i.e., those industries yielding decreased values to the region), pertain to those export industries *not* included in an optimal solution; that is, industries not among the set of optimal industries. The

[31]Multiple regression analysis is a statistical technique that estimates the effects of a number of causal, or correlative factors (independent variables) on the value of another (dependent) variable.

positive and negative shadow price measures the contribution of a small change in the level of an activity to the region's objective.[32]

Nine industry characteristics are chosen to explain the size and sign of the generalized shadow prices.[33] These characteristics are regressed against the generalized prices. The resulting regression coefficients relate industry characteristics to regional objectives. They may indicate, for example, that to increase gross regional product, plants that exhibit low ratios of capital to output need to be attracted.

This procedure has two advantages. It reduces a larger volume of computer printouts down to a few summary formulas. And it translates the results of the analysis from the less useful language of industry products to the more useful language of industry characteristics.

Multiple Regression—Results. The specific results obtained using this statistical method can lead to substantial insights for the planner in prescribing optimal economic development. These specific results include the value of the multiple R^2 and the levels of the partial regression coefficients.

For all but one of the eight regional objectives (i.e., for all but one of the corresponding generalized export shadow prices used as dependent variables), the amount of explanation represented by the multiple R^2 value ranges between 0.61 and 0.84.[34] There are 101 observations and nine independent variables.[35] The multiple R^2 values are significant at the 1-percent level or better, while the results discussed for the partial coefficients are significant at the 25-percent level or better. Many of these partial coefficient results are also significant at the 5- or 10-percent levels.

For each of the eight objective functions (regressions), a separate "residual plot" was obtained for the 101 cases in the sample.

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[32]Originally 15 explanatory variables were considered, but these were reduced to nine to reduce the possibility of multicollinearity by eliminating variables exhibiting high pairwise correlations.

[33]The "positive" and "negative" shadow prices explained above.

[34]For the total regional profits objective, multiple $R^2 = 0.45$.

[35]The 101 observations correspond to the 101 manufacturing export activities consisting of 56 four-digit SIC manufacturing industries shipping to an inner export ring, at a lower transport cost, and 45 of those same industries shipping also to an outer export ring, at a higher transport cost.

Each plot records the (standardized) predicted dependent variable on the horizontal axis, versus the (standardized) residuals measuring actual values minus predicted values on the vertical axis. If the regression equation is specified adequately—as, for example, in its assumption of linearity—the scatter of plotted points should show a fairly symmetrical (similar) pattern in the four quadrants around the origin.

Such a symmetrical pattern obtains for all objectives but the two profit-type objectives—maximization of total regional profits and regional rate-of-return index. For each of these two regional objectives, there is some indication of linearity in the residual plot; this pattern is more discernible for the rate-of-return index objective than for the regional profits objective. For each of these two objectives, the relationship between dependent and independent variables may be better modeled as nonlinear, than linear. However, because this problem is not overly severe, the linear formulation (specification) was retained. Nonetheless, this suggests that the regression results for these two objectives may not be as accurate as for the other six objectives.

The results show an overwhelming importance of lower transportation costs in improving the desirability of export industries, almost irrespective of the regional objective chosen. Industrial location theory in regional analysis has exhibited a historical preoccupation with transportation cost. The results from this study support this focus. Using standard deviation units for both dependent and independent variables, a decline in transport cost leads, in general, to the largest relative increase in generalized shadow price.

Managerial labor, as a percentage of an industry's total employment requirements, is the next most important explanatory factor in determining the desirability of an export industry. For all eight regional (maximization) objectives, as the managerial labor proportion rises, the value of the objective falls. This result can be explained by the shortage of managerial labor in the Adjusted Planning Model, the specific version of RDAAP whose regression results are discussed here. In general, other model versions yielded similar results for scarce labor skills. In view of the high opportunity costs of managerial labor, one would expect the model to choose those industries that use less of this resource.

The skilled labor percentage of an industry's total employment shows an effect similar to that for managerial labor, but for only two of the eight regional objectives—gross regional product and local value added. Although skilled labor is not as scarce in the model as is managerial labor, the same (shortage) type of explanation still applies.

The capital/output ratio is generally the third most significant variable, 25-percent significant or better, in all eight regional objectives. In all but the two profit-type objective functions—total regional profits and regional rate-of-return index—increased capital intensity leads to lower levels of the regional objective. This result is consistent with the cottage industry type of development characteristic of more rural or underdeveloped regions. Increased regional profitability, however, seems to be linked to industries with higher capital/output ratios.

Another important finding concerns the value added/output ratio. For most objectives, a higher industry ratio increases the value of the objective. However, the two regional profit-type criteria reveal an opposite effect. For example, as the value added/output ratio rises, regional profits fall. Since the value added/output ratio is highly pairwise correlated with the wage/output ratio (or aggregate wage), value added/output perhaps can be considered a surrogate for wage/output. Thus, industries that pay out a larger percentage of their output in wages tend to improve most of the regional objectives, except for the regional profit-type objectives. This represents a dilemma in that the best industries for regional profit maximization are diametrically opposite of those required by most other regional goals.

The value added/labor ratio—perhaps a surrogate for the wage/labor ratio (or average wage rate)—is also an important variable in all eight objective functions. In all regional objectives but one—the rate-of-return index—industries of higher labor productivity yield increased values of the regional objective.

Both of these variables involving value added tell the planner that, in general, the best industries for an area tend to be those that pay higher wages, both in aggregate wage and in average wage rate. Thus, the usual "shirt factory" industry type of employment, with its low aggregate wage, and especially, low average wage rate, which is often attracted to rural and southern

areas of the United States, is not the preferred type of development for most regional objectives.

The industry variable measuring imported inputs per unit of output is the final independent variable statistically significant among many alternative regional objectives. It is significant for all but the two profit-type objectives—regional profits and rate of return index. The values for all other (non profit-type) objectives improve with industries of higher import costs. This suggests that an increase in regional specialization is desirable; that is, attracting industries with increased ratios of imported inputs.

This finding for the industry import cost perhaps can be explained or interpreted according to the analysis of Hirschman [*2*]. He suggests that the best way to achieve increased growth in an underdeveloped country (or region) is to pursue a policy of attracting industry in which merely the "finishing touches" are put on the disassembled imported inputs before they are re-exported. This implies a high percentage of imported inputs relative to the value of the final export product.

Other industry economic characteristics exhibit a statistically significant effect, but for only one or several regional objectives. Therefore, the policy recommendations derived from them are not as universal. Accordingly, these examples will not be discussed here but see [*18, 19*].

The multiple regression analysis presented here, as well as the objective function tradeoff analysis, can both be used to illuminate the inevitable conflict among alternative regional goals. For example, conflict can arise if a high regional wage bill, full local employment, and high regional profits are all desired goals. The proper planning prescription then becomes unclear. While the choice of industries with low capital/output ratio and high value added/output ratio tends to decrease aggregate regional profitability for the area's private industries, such a strategy also causes the local wage bill and local employment levels to rise. The region, therefore, must establish priorities among objectives before it can choose effective means to reach its objectives.

Agriculture

The optimal solutions for all model versions show that the conversion of all agricultural land in the regressive (lower income)

sector to progressive (higher income) farms is always beneficial, regardless of the regional objective. The fact that all optimal solutions yield total conversion of the regressive sector indicates that regional rural development should involve not only industrialization, but also a substantial improvement in the agricultural sector. The crucial importance of agriculture has recently been discovered by such third-world countries as India, where industrialization, which shortchanged the resources applied to agriculture, was seen by some as the sure road to progress.

The RDAAP model uses secondary data as contained in the *1964 U.S. Census of Agriculture* rather than using primary data from the BMW region in constructing the agricultural sector.[36] For the BMW region, such secondary data are sufficiently "area specific" to construct farm activities using data from Washington and Benton Counties. This methodology using area-specific agricultural data makes it much easier to adapt the model to other multicountry rural areas in the United States.

A common result for most RDAAP model versions and regional objectives is that only poultry and general farms are included in the solution. This result tends to support the model in that poultry is the leading agricultural activity in the BMW region. Also, only cropland is fully used while the three pasture categories remain up to 50 percent idle, indicating the model's high valuation (shadow price) on cropland (and crops), relative to pasture, hay, and pasture feeding animals.[37] For a more detailed presentation of the methodology used to construct the production activities in the agricultural sector of the model, see [*14*].

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[36]An interesting note is that the published data (national data for farm machinery and equipment, State data for farm service buildings) show the capital/output ratios to be higher for regressive than progressive agriculture (*1954 U.S. Census of Agriculture* for the former, and *USDA Farm Income Situation*, August 1968, for the latter). Therefore, agricultural progress is not always associated with increasing (relative) use of capital. Better organization of the farming operation and larger farm sizes are shown here to be more important.

[37]The somewhat unreasonable result of so much idle pasture represents a problem with respect to the rigidity of linear programming. However, it could be significantly alleviated by including activities (and relevant costs) to convert land from one type to another. But this is not attempted in any of the RDAAP model variations. Nonetheless, this result is consistent with the fact that pastureland is not used to capacity in the Ozarks.

Exports and Increasingly Open Economies

Successive increases in potential levels of both exports and labor incommuting can simulate what happens when an area becomes increasingly less isolated, and more open and integrated with the rest of the country. An earlier section examined tradeoffs between alternative regional goals which can be explored with this type of simulation. This section explores other general results of the simulation. In later sections—Basic Model (Expanding Regional Trade) and Adjusted Planning Model—more detailed results of this type of expansion will be presented.

When manufacturing export limits (constraints) are relaxed to very high levels from the initial relative lower base levels,[38] and the levels of labor incommuting permitted are greatly increased as well, the resulting industry spectrum in the model solution is specialized beyond what may be realistically obtainable or desirable for the planning area. This result is partly a reflection of the tendency of open economies to specialize and partly a problem with the assumptions of linear programming. If unconstrained, a linear programming solution selects "too much of the same things." In its linear world, costs and revenues of an industry remain constant, in opposition to the real world sequence of increasing, then constant, and finally diminishing returns. Export limits, at reasonable levels, such as are used in the base levels (see footnote 38) in the RDAAP model, are a means of coping with this problem. Or, more complex production functions of alternative scales could be added to the linear model to render it, in essence, less linear and, thus, somewhat more useful and realistic.[39] This latter procedure is not undertaken in the RDAAP model analysis.

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[38]Using a technique yielding very approximate results, my estimates of these base levels for exports represent what might be the region's natural share of the export market for each commodity. Therefore, these estimates can be considered as no more than "ballpark" figures.

[39]That is, the model would include several production functions for each industry, each with a different set of input coefficients to reflect varying relative costs and scale effects at each increasingly larger production level. After each such level is reached, the model would permit increased production by that industry only if it used its "next" production vector for that industry.

Planning Insights: Specific Observations From RDAAP Results

This section is divided into six subsections, corresponding to the various versions of the RDAAP model. Comments in the preceding section were usually general and tended to be valid for all model versions, whereas many of the results in this section are specific and hold true only for a particular version. This section presents some of the detailed numerical results of the various versions. The reader not interested in such details, may skip to the concluding section of this report.

The six RDAAP model versions in this section are as follows:

First, the Basic Model, as was described earlier.

Second, the Expanding Regional Trade version, which is the Basic Model extended by successively increasing both manufacturing export and labor incommuting limits.

Third, the Income Target Increase and Decrease version, which includes successive increases and decreases in the income target.

Fourth, the Total Model, which alters the simple Basic Model by adjusting all rows, columns, and coefficients which pertain to the incremental model in order to reflect a total model. That is, the total concept assumes the building of the region "from scratch."[40] Since this version is a terminal-year model, as are all RDAAP model versions, only the current production and the expanded capital requirements for the terminal year are included.

Fifth, the Planning Model, is essentially the version of the model as developed by SRI.

Sixth, the Adjusted Planning Model, described earlier, is built on the Planning Model foundation.

[40]In the base year of the planning decade, a zero level of regional capital stock is assumed.

These final two model variations are the planning versions of the RDAAP model. Table 2 lists selected structural details of all six versions of RDAAP.

Basic Model

The simple Basic Model was used to test whether optimal levels of employment could forecast actual employment growth in the BMW region over the decade of the sixties; the levels match up rather poorly with respect to industry types (SIC codes).[41] *Levels* of employment cannot be expected to correspond well since high levels of labor outcommuting (i.e., levels beyond what may be realistically expected) are observed in the Basic Model.[42] Hence, percentage *shares* of local employment levels in the model versus actual share results for the region are the figures compared. Here, too, the correspondence is poor. None of the six regional objectives of the Basic Model can be said to have predicted better than any of the others.

Comparison of Basic Model and BMW Region Employment in the Manufacturing Sector. For the manufacturing sector as a whole, the percentage of total employment ranges from 24 to 29 percent over all six regional objectives; for the area, the actual proportion of manufacturing in the growth increment was about 36 percent. The model, therefore, underestimates the actual growth of manufacturing.

For four-digit manufacturing industries, the matchup is also poor, due partly to the relatively small number (64) of manufacturing industries in the model. Slightly over 50 percent of the region's actual four-digit SIC manufacturing industries are not included in the model.[43] As a result, 44 percent of the region's

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[41]This problem might be substantially reduced if one would look at industry economic characteristics, rather than only at product type (SIC's). Due to a lack of data, such model/actual comparisons based on industry economic characteristics were not implemented [*18, 19*].

[42]Labor incommuting but not labor outcommuting is limited in the simple Basic Model. The latter assumption prevents the model's internal (shadow price) wage for any labor skill from falling to zero if it is in surplus.

[43]The area theoretically can obtain industries from approximately 450 four-digit SIC manufacturing industry categories.

Table 2—Selected structural details of the six versions of the RDAAP model

Six Versions of RDAAP:	**Simple Basic Model** **Basic Model (Expanding Regional Trade)** **Basic Model (Income Target Increase and Decrease)** **Total Model** **Planning Model** **Adjusted Planning Model**

Alternative regional objective functions: Their usage among model versions

Regional objective	*In the Adjusted Planning Model*	*In the other five model versions*
Regional balance-of-payments surplus	Used as objective function or as constraint row	Used as objective function or as constraint row
Regional balance-of-trade surplus	Same as above	Same as above
Gross regional product	Same as above	Same as above
Local value added	Same as above	Same as above
Local wage bill	Same as above	Same as above
Local employment	Same as above	Same as above
Regional profits	Same as above	Used as constraint row only
Regional rate-of-return index	Same as above	Same as above
Gross regional product (immigration)	Same as above	Not considered in these model versions

Continued—

Table 2—Selected structural details of the six versions of the RDAAP model—Continued

Selected changes in constraints and activities among model versions

	Simple Basic Model	*Basic Model (Expanding Regional Trade)*
Manufacturing export constraints	Base levels (incremental approach)	4 iterations (4, 8, 12, 16 times base level)
Labor incommuting constraints	Base levels (incremental approach)	4 iterations (2, 5, 8, 12 times base level)
Labor outcommuting constraints	None	None
Labor supply (right-hand-side portion)	Actual growth in BMW region labor supply	Actual growth in BMW region labor supply
Labor supply (released labor)	Fixed (target) portion from old sector; variable portion from regressive agriculture	Fixed (target) portion from old sector; variable portion from regressive agriculture
Number of labor transfer activities	One	One
Per capita personal income target	Same as BMW region, 1960-70	Same as BMW region, 1960-70
Number of column and row activities	394 columns, including RHS column, excluding slack vectors; 365 rows	394 columns, including RHS column, excluding slack vectors; 365 rows

Continued—

Table 2—Selected structural details of the six versions of the RDAAP model—Continued

Selected changes in constraints and activities among model versions

	Basic Model (Income Target Increase and Decrease)	*Total Model*
Manufacturing export constraints	Base levels (incremental approach)	Base levels (total approach)
Labor incommuting constraints	Base levels (incremental approach)	Base levels (total approach)
Labor outcommuting constraints	None	None
Labor supply (right-hand-side portion)	Actual growth in BMW region labor supply	Actual BMW region labor supply
Labor supply (released labor)	Fixed (target) portion from old sector; variable portion from regressive agriculture	None
Number of labor transfer activities	One	One
Per capita personal income target	4 successive increases; 4 successive decreases from that of simple Basic Model	Same as BMW region, 1960-70 (with total approach)
Number of column and row activities	394 columns, including RHS column, excluding slack vectors; 365 rows	390 columns, including RHS column, excluding slack vectors; 359 rows

Continued—

Table 2—Selected structural details of the six versions of the RDAAP model—continued

Selected changes in constraints and activities among model versions

	Planning Model	*Adjusted Planning Model*
Manufacturing export constraints	Base levels (incremental approach)	Base levels (incremental approach); 2, 3, 4, 5, 6 times base levels for iterations 1-5, respectively
Labor incommuting constraints	Base levels (incremental approach)	Base levels (incremental approach); 6, 12, 18, 24, 30 times base levels for iterations 1-5, respectively
Labor outcommuting constraints	None	5 percent of model's labor supply level for each labor skill
Labor supply (right-hand-side portion)	Uses SRI projection technique for labor supply by skill level	Uses SRI projection technique for labor supply by skill level
Labor supply (released labor)	Fixed (target) portion from old sector; variable portion from regressive agriculture	Varies depending upon size of wage bill plus "other income" in model; variable portion from regressive agriculture
Number of labor transfer activities	One	Six
Per capita personal income target	Same as BMW region, 1960-70	No target; varies depending upon size of wage bill plus "other income" in model
Number of column and row activities	394 columns, including RHS column, excluding slack vectors; 365 rows	400 columns, including RHS columns (2), excluding slack vectors; 370 rows

observed growth in manufacturing employment is in industries not incorporated in the model.[44]

The correspondence improves only very slightly at the three-digit and the two-digit SIC classification levels. This limited improvement can be explained by the successively increased "potential" for matchup. But at these aggregated levels, the matchups have less meaning and precision. Two industries classified as different at the four-digit level, but which fall into the same three-digit category, would probably have less in common than two industries in the same four-digit classification.

Some four-digit level employment comparisons in the manufacturing sector follow. Poultry processing, an extremely important activity in the area, represents about 21 percent of the region's manufacturing employment and about 7 percent of the total employment in the region. However, the largest corresponding percentages for the model are 3.7 and 0.9, respectively (for the local employment objective). For the value added and local wage bill objectives, poultry processing is not in the solution at all.

The second largest manufacturing industry in the area is for motors and generators, but since there is no such industry in the model, no prediction of this industry is possible. The third largest in the area is knitting mills (except knit fabric mills) which is in the model solution for only one of the six regional objectives (the local employment objective) at only one-fourth the actual level for the region.

Conversely, the refrigeration machinery industry is the largest (in terms of employment) and most important in the model (largest shadow price) for all regional objectives, but does not exist in the area. Even when this industry is considered at its three-digit level—service industry machines—there is very little corresponding regional employment.

There are a few isolated examples of a good fit at the two-digit level, but overall the correspondence is not much improved from

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[44]If one looked at the economic characteristics of the region's industries, and compared them to the corresponding model industry characteristics, a lack of potential for SIC code matchup would be less important (see footnote 41).

the three-digit or four-digit level. Thus, in general, the aggregation of industries improves the model's predictions very little.

Comparisons of Service, Government, and Agricultural Sector Employment between the Basic Model and BMW Region. The model is a poor predictor of service sector employment. Among the model's six alternative objectives, the service employment percentages remain relatively unchanged. This is not surprising since there are (assumed) no exports or imports of model services. Thus, the only changes in service demand can arise from changes in intraregional interindustry demand.

Prediction by the model of the actual increase in government employment for the region has no meaning because the number of government employees in the (Basic) model is defined as the actual increase for the region.

The agricultural sector shows a net employment change (progressive minus regressive sector) that is generally in the same direction as that of the region. The area's agricultural employment declined in the sixties. The model predicts a net decline in agricultural employment for all objectives but the local employment objective. Thus, the model to some extent describes or predicts the area's agricultural employment decline.

Employment Comparisons by Sector between the Basic Model and BMW Region—Conclusion. The conclusion that one can make for planning purposes, in view of those generally poor predictions, is to rely less on specific model (SIC) detail, and more on industry economic characteristics when making comparisons between actual and model industries. That is one reason that many of the findings in this report are discussed in general terms rather than in specific numerical or industry detail. Poor prediction, however, does not necessarily imply that the model solution would have been a poor prescription for an area's economic development.

Comparing Unconstrained and Optimal Levels of Each Regional Objective. There are six objective functions in the Basic Model. When one is maximized, the other five are unconstrained or constrained to be above a minimal level. In this section, only balance-of-payments surplus is constrained. Comparing the resulting levels of unconstrained function values of an objective with its feasible maximum is informative. For the Basic Model,

the regional balance-of-payments surplus for the capital-oriented objectives is around $12 million, compared with a possible maximum of $13 million.[45] For all labor-oriented objectives, the balance of payments falls to its constrained floor of zero. The regional balance-of-trade surplus, similar to the payments surplus but not augmented by net investment and profits flows, shows a similar pattern. When the trade surplus is maximized, the trade deficit is about $19 million; when the balance of trade is unconstrained under the maximization of the local wage bill, the trade deficit rises to $36 million.

Gross regional product, which is defined here to include in the "foreign trade" sector the net wages of outcommuters above incommuters, exhibits values that cluster at a substantially higher level for the capital objectives than for the labor objectives. Its range of values is from a high of $191 million for the gross regional product objective to a low of $177 million for the local wage bill objective. However, if outcommuting labor wages are not included, gross regional product for the labor objectives slightly exceeds that of the capital objectives (except for the local wage bill objective). Apparently it is only the sizable levels of labor outcommuting receipts that enable the capital-oriented objectives to achieve a greater gross area product than the labor-oriented objectives.

If sizable levels of labor outcommuting[46] are not acceptable, then the above results for gross regional product provide some evidence of the desirability of (1) labor-oriented rather than capital-oriented regional objectives, and (2) objectives that use such labor resources locally with less reliance on interregional exchange. The pattern for aggregate value added and regional wage bill (when outcommuting wages are included or excluded) is similar to that for gross regional product.

For local employment, the capital objectives' employment opportunities in the region are about 6 million worker-hours fewer than the labor objectives'. However, when the outcommuted labor is added to the local employment total for each objective, each result, by definition, will be the same: the total local resident labor force.

[45]All dollar values are in 1963 constant dollars.

[46]The implication of these large levels of labor outcommuting will be discussed shortly.

Labor Outcommuting. The Basic Model yields high levels of labor outcommuting.[47] In view of this, most regional macroeconomic variables, such as regional wage bill, regional value added, etc., are listed in two forms—with and without wages accruing to labor outcommuting.

What would represent a reasonable level of labor outcommuting? According to Berry, no more than 5 percent of the labor force outcommuted from the BMW region (Fayetteville) in 1960 [*1*]. Accordingly, the residual resulting from deducting this 5 percent from the level of labor outcommuting in the optimal solution, can be considered as an approximate indicator of regional unemployment. However, to insure that the internal prices (shadow prices) of labor skills in the model do not fall to zero, the model permits an unlimited potential for labor outcommuting. That is, the model does not limit the external (to the region) wage opportunities.[48] This represents a more realistic model solution since, in reality, labor wages are not zero.

The above 5-percent labor commuting level can perhaps be considered as the "natural" level of labor outcommuting. But even with the 5-percent deduction, the level of "excess" outcommuting, or unemployment, is high in the Basic Model. This is troublesome because the constraint levels for exports and incommuting labor assumed in the Basic Model were felt to be reasonable.[49] However, as will be discussed later in this report, the very modest changes incorporated in the Adjusted Planning Model greatly improve this result (i.e., reduce unemployment).

Labor by Skill Level—Supply and Demand Patterns. The excessive level of labor outcommuting (unemployment) in the Basic Model suggests that the optimal results use a different

[47]In the SRI model, all outcommuted labor was assumed to be unemployed, and the outcommuting wage sum (based upon reservation prices for the wage rates) was deducted from the total regional product.

[48]Only if the regional objective is measured in dollar units will the shadow (wage) price also be in dollar units. Thus, a shadow price wage need not necessarily be calculated in units of currency, as would be typical for a wage in a money economy.

[49]In extensions of the Basic Model, these constraints are successively increased. The base-level export constraints represent a very approximate calculation for export markets based on very rough estimates of the historical export shares of the area industries.

pattern of labor skills than actually prevails in the area.[50] Again this shows that the Basic Model is an inadequate predictor of the actual BMW region. Table 3 summarizes the pattern of labor use and availability in the model for the objective of maximizing the regional balance-of-payments surplus.

Table 3 is divided into two main sections—the BMW region and the RDAAP model. The first two rows of percentages for the BMW region are from table 1 and give the percentage breakdown by skill level of total employed labor in 1960 and 1970. The third row is the percentage breakdown of employment growth in the region between 1960 and 1970.

The second section (RDAAP model) gives, first, the total labor supply included in the model. For the Basic Model, this supply includes not only the 1960-70 regional labor growth (row 3 of the table), but also additional labor (explained in table 3 footnotes) due to productivity growth in the old sector, to technical and organizational change in agriculture, and to incommuting. This sum then represents the (Basic Model) supply of labor available to the model; it differs from the BMW region growth of labor alone, as can be seen by comparing the percentages in row 4 with those in row 3 in table 3. The model's growth in labor supply for unskilled and, especially, skilled labor, relative to the model's total growth, is larger than that for the region; the model's growth in supply is smaller for managerial and, especially, clerical labor.

The demand for labor in the Basic Model (row 6 in table 3), consists of the total percentage use of labor in the model, excluding labor outcommuting. When outcommuting labor is included (row 7), the demand percentages equal, by definition, the supply percentages (row 4). Comparison of these labor demand and supply percentages (rows 6 and 4) reveals a poor matchup between regional labor supply and demand of the Basic Model. The differences are accounted for by commuting.

The labor supply (row 5) and demand (rows 8 and 9) for the Adjusted Planning Model are defined somewhat differently as

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[50]The actual increase in the labor supply for the BMW region is not exactly identical to the model's total labor supply because the latter includes "released" labor from both the old sector and regressive agriculture, and from limited levels of incommuting labor. This extra supply is added to the actual growth in labor supply by skill level for the BMW region to form the model's total labor supply.

Table 3—Growth in employed labor force, by skill level, 1960-70, actual compared with model

Item	Managerial	Clerical	Skilled	Unskilled	Total
			Percent		
BMW region[1]					
1960 (total)	18.5	8.6	44.6	28.4	100.
1970 (total)	20.0	12.6	40.1	27.3	100.
1960-70 (growth)	23.5	21.9	29.9	24.7	100.
RDAAP model[2]					
Labor supply, 1960-70					
Basic Model[3]	19.6	15.2	39.1	26.1	100.
Adjusted Planning Model[4]	13.8	14.7	22.8	48.7	100.
Labor demand, 1960-70					
Basic Model	22.7	22.8	18.0	36.5	100.
Plus out-commuting labor	19.6	15.2	39.1	26.1	100.
Adjusted Planning Model[5]	15.0	15.9	24.8	44.3	100.
Plus unemployed labor	13.8	14.7	22.8	48.7	100.

[1]Calculated from [9].

[2]For the objective of maximizing the regional balance-of-payments surplus.

[3]This row includes the actual increases for employed labor for the BMW region (1960-70), plus the "released" labor from the 1960 BMW region (old sector), plus the "released" labor from regressive agriculture. It also includes (model) incommuting labor, which is constrained to be less than or equal to 5 percent of employment growth (1960-70), by skill level, in counties contiguous to the BMW region.

[4]This row includes projected, not actual, employed labor increases for the BMW region (1960-70), plus labor transfers between skills via (constrained) transfer activities for the labor skills. Additional labor supply sources (although not necessarily labor supply levels) are identical to those in footnote 3 of this table.

[5]Outcommuting labor is included in both of these rows of percentages because it is limited to low levels in the Adjusted Planning Model. Unemployed labor—not excessive in this model version—is included in the percentages in the second row.

explained in the footnotes to table 3. Demand (row 8) differs from supply (row 5) in the Adjusted Planning Model to the extent of unemployment (included in row 9). However, the matchup here between supply and demand is much closer than that for the Basic Model because of the Adjusted Planning Model's mechanism for adjusting both demand and supply.

Although neither the Basic nor Adjusted Planning versions of RDAAP "predicted" extremely well the use of labor by skill level in the model—demand did not equal supply—such a discrepancy is likely to be irrelevant. The RDAAP model is designed primarily as a *planning* and not as a *predictive* model; there is no necessary reason why actual growth (including "released" labor, etc.) has to precisely mirror optimal model growth for any of the regional objectives. In fact, one might feel, all other things being equal, that at least several regional objectives would yield results that differed substantially from those observed. The Basic Model was constructed to inquire into the model's predictive potential; however, the RDAAP model's main purpose is to describe optimal regional growth and development for alternative regional objectives, not to predict regional growth.

Labor By Skill Level—Unemployment Rates. Some labor is not in excess supply in the Basic Model. Clerical labor is in short supply; this shortage is the main reason for the "excess" of other labor skills.[51] If one assumes all excess outcommuting labor to be unemployed, the Basic Model unemployment rates reveal the dichotomy between the capital and labor objectives observed earlier. For the capital-oriented objectives, unemployment averages around 29 percent, while for the labor-oriented group, unemployment ranges from 19 to 22 percent (table 4).

Managerial unemployment ranges between 16 percent for the gross regional product objective to 20 percent for the local wage bill objective. Skilled labor unemployment averages about 64 percent for the capital objectives and from 45-52 percent for the labor objectives. Unskilled and clerical labor generally are used fully. The Basic Model finds it advantageous to train unskilled

[51]The rigidity of labor requirements is a problem because of the constant coefficient nature of linear programming (although alternative scale vectors could help; see footnote 39). The rigidity of labor supplies by skill level further exacerbates the situation. The Adjusted Planning Model attempts to alleviate, at least partially, this latter rigidity.

labor, and outcommute newly trained workers (as skilled workers), with the BMW region reaping the benefits only in terms of external wage earnings. This is perhaps not a sensible solution—training workers for jobs that do not exist in the local area, with the assumption that there will be significant employment opportunities outside the region.[52] The shortage of clerical labor is a bottleneck to growth in the region;[53] jobs cannot be created to use the available managerial, skilled, and unskilled labor until this bottleneck is broken.

Labor By Skill Level-Shadow Price Valuations. The wage floor, below which the model's internal price of a labor skill cannot fall, is determined by the assumed wage levels for labor outcommuting. For capital objectives, this wage directly measures the shadow price for "surplus" labor, because regional "foreign exchange" directly enters into the objective function. For labor

[52]The Adjusted Planning Model greatly reduces this excessive outcommuting problem for labor. Further refinements in the model, such as adding penalty costs (e.g., unemployment insurance, welfare costs, and so on) to excessive levels of labor outcommuting (unemployment), could further reduce the problem.

[53]Unskilled labor is not a bottleneck since it is available for use in the local area.

Table 4—Unemployment by skill level, by six objective functions: simple basic model, BMW region, 1960-70

Objective function	Managerial	Clerical	Skilled	Unskilled	Total
			Percent		
Regional balance-of-payments surplus	17.83	0	64.37	1.77	29.30
Regional balance-of-trade surplus	18.28	0	64.25	0	28.88
Gross regional product	16.55	0	64.04	.46	28.57
Local value added	17.91	0	51.56	0	20.77
Local wage bill	20.46	0	52.22	0	22.28
Local employment	18.20	0	45.88	0	18.98

objectives, a floor remains, but its level is determined only indirectly by the outcommuting wage, depending upon the relative shortage of "foreign exchange" with respect to the particular regional objective function and its units (e.g., dollars, manhours, and so on).

The shadow price valuation for clerical labor (the only labor skill in substantial short supply in the Basic Model) is well above its floor level. The shadow prices for the other labor skills equal their floor levels. Under the capital objectives, the clerical labor shadow price ranges from three to seven times its floor, a floor level that is about 40 percent of the floor level for managerial labor (the largest). Under the labor objectives, clerical labor valuation is about 30 times the managerial shadow price and about 46 times the floor level for unskilled labor. Thus, clerical labor is much more scarce for labor-oriented than capital-oriented objectives, but its shadow price levels are extremely elevated regardless of objective.

There is no necessary reason for a labor shadow price to equal the actual regional wage. Fixed labor coefficients and supplies by skill level, and the absence of a mechanism for handling relative prices and wages in a linear model, would all tend to lead to a divergence between the actual wage and its corresponding shadow price. Even if one could eliminate such rigidities, at least some regional objectives (even among those in dollar units) would probably still yield labor shadow prices that differ from actual wages.

Basic Model (Expanding Regional Trade)

In the Expanding Regional Trade version of the Basic Model, the manufacturing export limits and incommuting labor constraints are simultaneously increased in four successive stages or iterations. This successive relaxation of constraints simulates the gradual opening of the region to increased trade and labor flows with the rest of the country; such increased flows induce increased growth in the area production and a rise in the region's industry specialization. The initial or base levels of these trade and commuting constraints (for the simple Basic Model) approximate benchmark figures. This section will explore in some detail the effects of the expansion.

Export limits are raised up to 16 times, and incommuting labor ceilings up to 12 times their initial levels, in four separate iterations. Export markets and incommuting labor flows at such large levels are not likely to occur.[54] Nonetheless, the exercise can prove informative. The results show a rapid increase in specialization; the optimal number of industries declines precipitously during early iterations, but falls more slowly during later ones.

As export and labor incommuting constraints are raised simultaneously over the four iterations, employment increases substantially in all industries (service and manufacturing) and gross output in the region expands as well. For example, the manufacturing employment subtotal is two and one-half times larger at the upper level than at the initial level. If an industry fails to appear in a lower iteration solution, it does not necessarily indicate that it will not enter in a higher iteration. For example, for the local employment objective, some industries absent from the lower steps, enter at extremely large levels in later steps.

Over these four expansion steps, the most important industry in the model solution remains refrigeration machinery, its size rising from around 850 employees for all objectives in the initial level to 14,300 employees for the local wage bill objective in the final step. The next most important industry in this last step is manufacture of male underwear and work clothing, which increases to an employment level of about 3,500 workers for the local employment objective. However, at the two intermediate expansion steps, this industry disappears from the solution for this objective.

As might be expected, as the permissible constraint levels are raised, and the area becomes much more open and productive, the deficits in both the government and consumption accounts fall (for a given fixed income target), resulting in substantial surpluses at the upper expansion levels (except for the consumption account for the local employment objective). These extremely large increases in trade and labor flows lead to a high degree of industry specialization, and such specialization may deal a region a longrun destabilizing blow if long-term or

[54]As will be explained later when discussing the results for the Adjusted Planning Model, increased levels of incommuting can be interpreted as simulating the inclusion of more labor retraining activities in the model.

cyclical reductions in demand should occur for the region's few export products.

The effect of the series of expansions on the level of "excess" outcommuting (above 5 percent of regional labor supply)—in other words, unemployment—is as expected: outcommuting and, therefore, unemployment decline substantially. For the labor-oriented objectives, unemployment drops to nearly zero at the higher steps. But for the capital-oriented group, some unemployment remains, even at the highest step, although it is reduced to around 5 or 6 percent.

The main effect on the labor valuations (shadow prices) of this successive relaxation of constraints is to bring the clerical valuation slightly more in line with the shadow prices of the other three labor skills. This is accomplished more by an increase in the latter three valuations than a decrease in the clerical price. In the later expansion steps, the huge increase in clerical labor which commutes into the BMW region creates a more even balance among the labor skills.

For the four types of agricultural land (total farmland available is assumed constant), both their usage and shadow prices change very little between the expansion steps. The optimal agricultural format changes very little as the region is opened to the rest of the country. However, this is less true for the labor-oriented regional objectives than for the capital-oriented ones.

Basic Model (Income Target Increase and Decrease)

In the income target variation of the Basic Model, the target for per capita personal income is successively raised in four steps from a 55.3-percent increase (simple Basic Model target) to a 75.3-percent increase, and then lowered in four additional steps to a 35.3-percent increase above the 1960 level. This experiment was run using only the regional balance-of-payments surplus objective.

The region's increasing per capita income target cannot be met without outside subsidy or other concurrent changes. Such changes consist of opening the region to larger permissible exports and labor flows, and of increased flexibility in labor supplies as included in the Adjusted Planning Model. Gross area

production remains virtually unchanged for increases in the income target, while production falls with decreases in the target.

The implementation of these increases (or decreases) in the income target involves a corresponding increase (or decrease) in both the consumption and government spending requirements. Increases in both these items are met merely by subsidies from outside the area. Both the regional balance of trade and payments surpluses are greatly reduced in order to "pay for" these larger targets. Correspondingly, the wage and tax deficits rise, indicating increased fiscal insolvency.[55]

As the per capita income target is reduced, gross regional product declines.[56] The region has no reason to produce, after meeting the reduced targets, other than to earn net regional "foreign exchange." Only that portion of extra production which adds to this surplus is undertaken. Similarly, regional wage and tax deficits decrease, changing to a surplus for the lower income targets.[57]

When per capita income targets are raised, the unemployment rate increases substantially because the model cannot use its labor as efficiently as before the increases. The model is forced to produce increasing amounts of goods and services for the consumption and government sectors, which results in an increasing surplus of some of the labor skills. This increased surplus then leads to a rise in the level of outcommuting. However, when targets are reduced, unemployment declines only slightly. The increase and decrease of the per capita income targets affect labor and land valuations (shadow prices) and land usage very little. In short, it is important that planners set targets that are feasible. Targets based on wishful thinking can lead to inefficient resource allocation as well as to dashed hopes.

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[55]That is, neither consumers nor government earn a sufficient wage bill or collect enough taxes to afford the targets.

[56]The regional balance-of-trade surplus objective should yield a similar result. It is not *a priori* clear what would happen for the other alternative regional objectives.

[57]This does not imply, however, that the improved fiscal situation for consumers and government is necessarily beneficial. In fact, excess wage and tax earnings (or, in other words, increased savings and tax surplus) may result in too much deferred consumption beyond the time-frame of the model.

Total Model

The Total Model embodies a "total" rather than an "incremental" approach. Otherwise, it is similar to the Basic Model. This version helps to answer questions of development from an assumed zero-level of capital stock instead of from the old-sector level in the base year.[58] The total investment in capital stock over the planning decade must achieve the same *per capita* income goal as the Basic Model in the target year. Would the industry mix differ for a total approach from that for an incremental approach?

Constraint limits on exports and labor incommuting, as well as the *aggregate* income targets (consumption and government), are raised slightly from those levels in the simple Basic Model to reflect the region's total population and labor force. All agricultural land is available for use including that used by the old progressive sector. The general conclusion of this experiment is that the marginal and total models are quite similar.

The Total Model does not give much new information about the optimal number and variety of industries compared with the results obtained using the Basic Model. This result perhaps should be expected because, in general, industries favored in a linear programming situation will continue to be favored as export limits are permitted to expand modestly. Only with sizable expansions will substantial numbers of these industries be curtailed. In short, what is optimal marginally tends to be optimal totally.

Some differences in the results of the Total Model from those of the Basic Model are worth noting, however. While the growth in employment in the Basic Model is less concentrated in manufacturing than is the actual growth for the BMW region, the total employment of the Total Model is even less concentrated when compared with the total employment for the region. The regional balances of trade and payments yield much larger deficits, partly because of the increased capital construction burden. But this is an incomplete explanation. Private investment levels in the optimal solution of the Total Model rise very little from those of the Basic Model. The difference is that the increased government and consumption requirements from those

[58]See footnote 40.

of the Basic Model, even with the Total Model's augmented labor supply, lead to reduced labor efficiency, resulting in increased levels of labor outcommuting in the Total Model. This suggests that perhaps the labor released from the old sector was actually less than estimated for the Basic Model; the old sector's increase in efficiency may have lagged behind the new sector's.

Thus, without appropriate changes in the model, such as are included in the Adjusted Planning Model, there is a problem with the Total Model as presently constructed. There is insufficient labor working in the region to produce the substantial capital production needed to reconstruct the old sector's capital stock. The regional wage bill deficit and the tax shortage are both increased using the Total Model.

The pattern of land and labor valuations (shadow prices) is similar in the Basic and Total Models. By definition, more land is available for reallocation among alternative uses in the Total Model, and as a consequence, usage rates are higher for some land types, lower for others. Cropland, however, is used fully in both models for all objectives.

Planning Model

The Planning Model differs from the Basic Model in one important feature. The supply of labor skills is determined by an estimation technique.[59] This represents a partial planning model; a complete planning model would require all target-year parameters to be projected from base-year data.

In general, the results from this planning model prove to be inadequate. This version is less useful for developmental purposes than the Adjusted Planning Model, which goes beyond the SRI formulation, and which is discussed in the next section.

The main flaw in the Planning Model lies in the projection technique, developed at SRI, for labor skills. The distribution of projected labor skills differs substantially from the distribution of

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[59]The actual BMW region population for 1970 is used for these calculations, but the labor force by skill level is estimated. The technique developed by SRI is used for this estimation.

actual skills in 1970 for the BMW region (table 3, row 3).[60] The Planning Model projects far less managerial labor than actually existed and, conversely, it projects more clerical labor, as well as a greater increase in total labor force than actually occurred by 1970 [9]. Accordingly, managerial labor is in short supply in the Planning Model, as was clerical labor in the Basic Model. Labor supplies by skill level are made more flexible in the Adjusted Planning Model.

The maximum level of regional balance-of-payments surplus attainable in the Planning Model is about $2.5 million, versus about $13 million in the Basic Model. This reduction is due to the assumed changes in quantity and quality of the labor force. Similarly, gross regional product is slightly reduced.

Excess labor outcommuting (unemployment) increased for all but managerial labor in the Planning Model. Deficits increased in the wage bill and tax accounts with respect to consumption and government spending. Realized income (wage bill) and taxes collected decreased. These results imply a significant criticism of this version's estimation technique for labor skills.

Adjusted Planning Model[61]

The Adjusted Planning Model improves upon the Planning Model, especially with respect to reducing excess labor outcommuting (unemployment). In this model version, the regional balance-of-trade surplus, rather than the regional balance-of-payments surplus, is constrained at or above a certain minimum level for all objectives. This should eliminate any tendency for outside investments to be made in low rate-of-return industries for the sake of an improved balance of payments. When the regional balance-of-payments surplus, which includes investment

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[60]This projection represents a major portion, but not the entire supply of labor in the model. "Released" labor from the old sector, regressive agriculture, and incommuting adds to the supply (see table 3 footnotes for the Basic and Adjusted Planning Models).

[61]Some of the analysis and results of this subsection may be difficult for the nontechnical reader; they can be bypassed without too much loss of continuity.

as a positive increment and profits as a negative increment,[62] is constrained to be above a certain minimum level (as in the Basic Model), then when the balance-of-payments row is binding, the solution may include industries of low rates of return in order to increase investment and decrease profits. This could have developed, but did not, in the Basic Model. Constraining the trade rather than the payments balance circumvents this possibility.

Three additional regional objective functions are added to the six of the Basic Model: maximization of total regional (private) profits, maximization of regional industry rate-of-return index, and maximization of gross regional product (with labor incommuters of the optimal solution to the original gross regional product objective assumed as immigrants).[63] Use of the first two added objectives has been discussed earlier in the section discussing attracting industries to the planning area and in the section describing the use of multiple regression analysis. The third added objective enables the planner to consider the nature of development with immigration, rather than incommuting only, of labor with critical skills.

That portion of the model's total labor force (by skill level) which is contained in the model's right-hand-side column remains unchanged from the Planning Model. Both consumption and government spending are required in this model to equal, respectively, the regional wage bill (excluding personal taxes and savings) and the area taxes collected. Although this requirement eliminates excessive deficits, it also permits the ratio of government spending to personal income to diverge from its historical norm.

In the Basic Model, each spending target represents an estimated percentage (rural Southern average) of both consumption and total taxes to the personal income target. In the Adjusted Planning Model, the consumption and government spending

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[62]All financing and ownership of incremental industrial investment in the region is assumed to originate from outside the region; profits remittances therefore flow out of the region.

[63]For this "immigrant version" of the gross regional project objective, the labor force (plus dependents) which immigrates is assumed to be the largest observed number of incommuting workers for the gross regional product objective. This occurs with the most "open region" run of the Adjusted Planning Model (for the same objective function, but without the immigration assumption). Incommuting and immigration are both permitted in this version.

levels, as well as the realized level of personal income, can vary. The benefit of handling consumption, government, and personal income in this manner is that they become *internally* consistent in the model. That is, not only are achieved levels of consumption and government endogenous, but also they are consistent with the levels of the endogenous wage bill (plus "other income") and taxes.

Similarly, the levels of three other activities in the model—the amount of labor "released" by the old sector, the level of investment targeted for that old sector, and the net level of the region's "other income"—are made to depend not upon an exogenous income target, but rather upon the gain in per capita income achieved within the model.

Labor By Skill Level—Labor Outcommuting Constraints. To measure true unemployment levels, labor outcommuting constraints by skill level and five additional labor conversion (transfer) activities are added to the Adjusted Planning Model.[64] The cost of this, however, is the loss of the model's internal wage floor on a surplus labor skill. In linear programming, the shadow price on a surplus resource is zero. The unemployment rates in the Adjusted Planning Model are more realistic and much reduced from the excess outcommuting levels of the simple Basic Model.

Labor By Skill Level—Labor Transfer Activities. The five added conversion activities between pairs of labor skills are limited to transfers which can be expected to occur without substantial retraining. Since the cost of such transfers would be very small, these transfer vectors need not include resource inputs. These potential conversions represent a very small fraction of the total labor force.

The conversions included are: (1) all managerial labor is assumed able to perform clerical labor tasks;[65] (2) some of the clerical labor

[64]The only such labor conversion activity in the Basic Model is the skilled labor training vector, converting unskilled workers into skilled. The outcommuting constraints are limited to 5 percent of the local supply of each labor skill; this percentage was cited earlier when discussing the work of Berry [*1*].

[65]This potential transfer, however, is unnecessary because managerial labor is in more short supply than is clerical labor in this model version.

can become managers;[66] (3) a small percentage of the increase in male high school graduates (half of whom join the managerial labor pool) can be transferred to clerical labor; (4) a portion of the clerical labor force is permitted to be used as unskilled labor (and is eligible for skilled labor training); and (5) some of the female skilled labor which is released from the old sector can become clerical labor.

Increase of Export and Labor Incommuting Constraints. The Adjusted Planning Model was used to simulate the operating of the region with respect to the rest of the country by simultaneously increasing the constraint levels for both exports of manufactured commodities and labor incommuting over five successive iterations above the base level.[67] Over the five iterations, the export constraints increase up to six times, and the labor incommuting limits up to 30 times the base levels. Labor incommuting increases of this magnitude are not realistic, but are included to simulate what might occur when labor transfer and retraining vectors are included.

For the base-level constraints, the industry-wide profit rate of return on investment for the region varies among objectives from about 18 percent to just under 14 percent, a realistic range of values. The regional balance-of-payments surplus (unconstrained in this model) generally decreases for the labor-oriented objectives as the economy becomes more open, although for the capital-oriented criteria there is no smooth trend; the surplus generally increases up to iteration 3, but decreases thereafter.

Consumption and Government Spending. In all but the regional balance-of-trade and balance-of-payments maximizations, the levels of consumption and government spending require no floor because additions to these tend to increase the values of the other regional objectives. But for the trade and payments criteria, reducing consumption and government spending tends to increase the surplus by reducing the need for imports. Although all wages[68] and taxes earned in the model are required to be

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[66]The Planning Model assumes that all (and only) high school female graduates form the clerical labor supply. This model allows a certain percentage of these females to become managers.

[67]This base level is identical to that in the simple Basic Model.

[68]The portion of the wage bill that is spent is that part that excludes personal taxes and savings.

spent, there is an incentive for the model to yield low consumption and government results for these two objectives. Hence, increasing minimum levels of consumption and government spending are required over the five iterations. Also, the balance-of-trade surplus minimum is decreased at each step to permit a greater variety of activity in each solution.

Consumption and government spending levels achieved over the nine regional objectives of the Adjusted Planning Model rise steadily as the region is opened. At the base level, the per capita income target (consumption and government spending) which pertained to the Basic Model is not met.[69] In the Adjusted Planning Model, consumption levels for the base-level iteration vary among the various objectives but generally are reduced by 20 to 30 percent from the Basic Model target. This income target (and implicitly the consumption and government spending goals) was based upon the per capita personal income actually achieved in the BMW region for 1970.[70] A similar, but much less severe reduction obtains for the level of government spending in the base level of the Adjusted Planning Model.

These results constitute a criticism of the present model (at the base level) without more extensive labor retraining activities, since the spending targets were actually achieved in 1970 in the area. By iteration 1, government spending generally exceeds its target, and consumption spending remains only somewhat below the actual level for the BMW region for 1970. At the highest iterations, these goals were much exceeded.

The important conclusion is that the model gives per capita income results closer to those actually achieved in the area if exports and labor incommuting constraints are somewhat relaxed. Some increase in incommuting would be easily acceptable. But, instead of the vastly increased incommuting of the higher iterations, an increase in labor-retraining activities would be a more realistic way to achieve higher incomes. The inclusion of such labor reconversion activities should be a future priority in improving the Adjusted Planning Model.

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[69]The simple Basic Model met its income target with implicit subsidies from outside the planning area.

[70]The regional income estimate used is a BMW region/Arkansas aggregate income ratio, for 1970, times the actual per capita personal income for Arkansas in 1970.

The relaxation of export constraints for manufactures (raised simultaneously with increases in limits for incommuting) is easily of realistic proportions in the Adjusted Planning Model. That is, in the lower steps (e.g., 100-percent to 300-percent increases), such increases in the export markets are easily achievable in view of the very approximate estimation of the base-level export constraints. Nonetheless, excessive industry specialization resulting from extremely high permissible levels of exports is not a realistic or desirable prospect for the planning area.

Although the results obtained using the base-level constraints of this model version seem satisfactory, more meaningful results can be obtained by (1) a judicious opening of the model with respect to export and labor flows, and (2) some accompanying increase in the flexibility of the labor supply by means of additional labor retraining activities, converting surplus skills into those more critically needed.

Labor By Skill Level—Unemployment Rates. In the Adjusted Planning Model, unemployment arises because labor outcommuting is constrained to no more than 5 percent of the local labor force by skill level. In the base level for exports and labor incommuting, the regional unemployment rates for two of the nine objectives are zero—for the regional goals of maximizing local employment and gross regional product (immigrant version). This result for the immigrant version is to be expected since the portion of the labor force that the model assumes immigrates to the region is precisely those labor skills that were incommuted in the "prior run" and that were in short supply; immigration provides the needed balance in the labor force.

For the base level, the unemployment rates corresponding to the other regional objectives are also low. The rates rise to about 8 percent for the objectives of maximizing regional trade and payments surpluses. (The regional rate-of-return index objective is an exception with a 36-percent unemployment rate, highlighting again the conflict between labor and capital.) Therefore, for the base level, eight of the nine objectives yield realistic unemployment rates. Only managerial labor incommutes at the base level's 5-percent limit for contiguous counties to the BMW region. As the economy becomes more open, in iteration 1, five of the nine objectives show zero regional unemployment rates. By

iteration 5, the unemployment rates for all nine objectives have fallen to almost zero.

Labor Transfers Between Skills—Results. Using the regional objective of maximizing the balance-of-payments surplus, the results over the five iterations for each of the six labor transfer activities (including skilled labor training) are shown in table 5. These results are representative for all regional objectives, although there are some scattered exceptions. The labor transfers permitted represent only a very small fraction of the total BMW region's labor force.

Table 5 reflects that managerial and clerical labor are in short supply, whereas there is always an adequate supply of unskilled labor. At the base level, the transfer of clerical to managerial was at its upper limit, while some of the clerical pool was replaced by transfers from unskilled. As the economy becomes more open, the transfers from both unskilled and skilled to clerical reach their upper limits to replace some of the clerical labor transferred to managerial. Levels of skilled labor training (unskilled to skilled) decline to zero by iteration 2 because of the relative surplus of skilled labor. Only at iteration 5 does a small level of such training reappear.

Managerial and clerical labor are the only labor skills that are substantially scarce. Skilled and unskilled labor are at no time incommuted over the five steps, while clerical labor is increasingly incommuted beginning with iteration 1. Managerial labor, being extremely scarce, is incommuted over all six levels.

Labor By Skill Level and Agricultural Land (Shadow Price) Valuations. Shadow price (wage) valuations on labor skills for the objective function of maximizing the regional balance-of-payments surplus—and for most of the capital-oriented objectives—show managerial labor to be the most valuable over the five iterations. The managerial (shadow price) wage ranges from a high of $8.56 per hour in iteration 0 to a low of $3.27 in iteration 4, rising again in the last iteration. Clerical labor is the next most valuable, showing a range of $3.23 per hour to a low of $0.08. The wage range for skilled labor is $2.78 to $0.00 per hour, for unskilled $2.74 to $0.00 per hour. A shadow price "wage" of zero (e.g., $0.00) represents the linear programming valuation of a surplus (slack) resource. It does *not* mean that an

Table 5— Labor transfers between skills, regional balance-of-payments objective, adjusted planning model, BMW region, 1960-70

Labor transfer	Constraint limits	Iteration number					
		0	1	2	3	4	5
		10,000 worker-hours					
Managerial to clerical	No limit	0	0	0	0	0	0
Clerical to managerial	195.10400	195.10400	195.10400	195.10400	195.10400	195.10400	195.10400
Unskilled to clerical	80.36184	62.97441	80.36184	80.36184	80.36184	80.36184	80.36184
Clerical to unskilled	181.58400	0	0	0	0	0	0
Skilled to clerical	8.07123	0	8.07123	8.07123	8.07123	8.07123	8.07123
Unskilled to skilled	315.74400	252.76959	207.74304	0	0	0	57.58052

actual wage in a region would be zero. The shadow price wages are not the wage rates assumed in the model. The production activities were designed so that the average wage rates assumed for labor vary not only among labor skills, but also among industries.

For the use and shadow price valuation of agricultural land, results are given for the objective function of maximizing the balance-of-payments surplus. Such results are representative of all the capital-oriented objectives. As in the Basic Model, only cropland is 100 percent used in the base level and that full usage continues over all subsequent iterations. Other land types show generally a decreasing percentage usage rate over iterations 0 through 5. Since cropland is the only scarce land factor in the model, it yields the only land shadow price valuation. This cropland price varied between $303 and $353 per acre.

Conclusions

Prescriptions for planning economic development in rural areas using the results of this study (RDAAP) are difficult to assert with complete assurance because the model's results may be sensitive to the particular data and version of the model used, and they may pertain only to the specific area to which the study methodology is applied. Such sensitivity was not discovered in the sensitivity analysis that was performed, but since the scope of this analysis was quite limited, the possibility of more than modest sensitivity cannot be completely ruled out. However, one can expect the more general insights to hold for alternative applications. That is, those results observed repeatedly for many versions of RDAAP can be expected to have general validity for areas similar to the BMW region. Application of the *methods* used should have even wider scope.

Tradeoffs between alternative objectives are shown to be a universal planning problem. The range or size of the tradeoff is larger between a capital-oriented and a labor-oriented regional objective than between individual pairs within each category. Opportunity costs increase for end-points compared with costs for midpoints on the tradeoff curves. This suggests it may be better to achieve somewhat less than the maximum of one objective in order to gain sizable increments in another.

Interpreting model results in terms of industry characteristics instead of product mix increases the applicability of the linear programming model. Low transportation costs on exports of manufactured products are overwhelmingly the most important determinant of improved levels of regional objectives.

Industries with a low capital intensity relative to output, a high value added relative to both labor and output, and a high proportion of imported inputs relative to output are shown to yield, in general, higher values for regional objectives. Moreover, if a labor skill is scarce (e.g., managerial), an increase in its use by an individual industry lessens that industry's benefit to the community. These observations can be of use to the planner in selecting the types of industries most beneficial for the planning area.

The agricultural results from the RDAAP model show that it is always advantageous to convert farmland from the land use pattern of the lower income farms to that of the higher income farms. The model reveals that the more open an area is to labor and commodity flows, the larger is its total production, and the lower is its unemployment.

In constructing a model such as RDAAP, care must be taken to insure its conceptual integrity. As an example of this, RDAAP was improved by adding a sector which invests in and "releases" labor from the base-year economy. This creates a tie between the old and new sectors such that the increase in labor force between the base and target years will not have to produce the consumption and income increment for the old sector, in addition to producing the entire target-year level for themselves (the new sector).

The experiments with various model versions of RDAAP demonstrate that modest changes and improvements in the structure of the model can lead to results useful for regional planning. Models not specifically designed for predicting or forecasting cannot be expected to perform those functions adequately.

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